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HUMAN RESOURCES, LOGISTICS, AND COST FACTORS IN WEAPON SYSTEM DEVELOPMENT:

DEMONSTRATION IN CONCEPTUAL AND VALIDATION PHASES OF AIRCRAFT SYSTEM ACQUISITION

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This technical report has been reviewed and is approved for publication.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A methodology, the coordinated human resource technology (CHRT), was developed to quantify critical human resource, logistics, and cost factors throughout aircraft acquisition. Knowledge of these factors helps influence the selection of a system and support design approach. The factors quantified are manpower, training, technical documentation, and system ownership costs. Reliability and maintainability, both of which directly affect the foregoing, are also quantified. The CHRT methodology also implements an integrated approach to personnel, training, and technical documentation, and operates from a single, evolving consolidated data base.

This report describes two parts of a three-part demonstration of CHRT application on an aircraft acquisition program. Parts 1 and 2, respectively, use conceptual and validation (prototype) phase data on avionics and landing 1 over

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gear systems of the Advanced Medium STOL[1] Transport (AMST). The results are presented and evaluated for various design, personnel, training, and technical data alternatives. CHRT is demonstrated as an acquisition management tool which initiates the development of detailed logistic and cost data early in acquisition and provides data source continuity throughout acquisition. Part 3 of the demonstration will use data projected for the AMST minimum engineering development (MED) phase. This phase is similar to full-scale development.

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[1] Short takeoff and landing

SUMMARY

Problem and Objective

The Advanced Systems Division of the Air Force Human Resources Laboratory (AFHRL) has initiated a two-phase effort to integrate and apply five human resource technologies to the weapon system acquisition process as the coordinated human resource technology (CHRT). The five technologies are human resources in design trade-offs, maintenance manpower modeling, instructional system development (training), job guide development (technical manuals), and system ownership costing. Phase One, the integration of these technologies and the development of CHRT, is complete and is documented in AFHRL-TR-78-6, Volumes I, II, and III. Phase Two, the application of CHRT in a weapon system acquisition program, is being performed in three parts: Part 1, using conceptual phase data; Part 2, using validation phase data; and Part 3 using full-scale development phase data. Parts 1 and 2 are complete and are the subject of this report which documents the activity, results, and conclusions drawn from the conceptual and validation phase demonstrations. The results of Part 3 will be documented in a separate technical report.

Approach

The Advanced Medium STOL[1] Transport (AMST) was the acquisition program selected for CHRT application. The actual conceptual and validation (prototype) phases of the AMST acquisition were complete and data appropriate to each phase were available when this demonstration began. For each phase of the demonstration, the data were compiled, the baseline and alternative system and support design approaches were identified, and the CHRT process was applied. The term system design, as used in this report, refers to the hardware and software design while

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[1] short takeoff and landing

the term support refers to the logistic support element design. During the course of the demonstration, the CHRT techniques and data products were evaluated. The techniques were improved, added to, or deleted where necessary. Data product presentation was also improved. In all cases, CHRT was applied as it might be by a system program or acquisition logistics manager.

Results and Conclusions

The results of each phase of the demonstration are analyzed and conclusions drawn regarding the methodology used to derive the results. In cases where modification to the methodology was determined appropriate, the effectiveness of the modification is also evaluated.

Three major objectives of this demonstration have been achieved:

A. Manpower requirements, training requirements, technical manuals requirements, reliability, maintainability, and system ownership costs have been quantified for several system and support design alternatives and at various levels of equipment detail.

1. During the conceptual phase demonstration, requirements and costs were quantified for the following designs:

    - A two-man flight deck avionics suite
    - A three-man flight deck avionics suite
    - A new landing gear
    - A modified landing gear

2. During the validation phase demonstration, requirements and costs were updated and quantified at the subsystem level for the following designs:

    - A two-man flight deck avionics suite
    - A three-man flight deck avionics suite
    - A modified landing gear
    - An integrated digital avionics suite

Assessments were also made at the subsystem level (a sub-set of a major system) for:

- Standard Station Keeping Equipment
- Insertable Station Keeping Equipment

B. A new technique to implement an integrated approach to training and technical manuals early in acquisition has been developed. Two basic approaches have been considered. One, the conventional approach, assumes primarily five-level personnel on the flight line, supported by conventional training and standard technical manuals. The other, the task-oriented approach, assumes primarily three-level personnel on the flight line, supported by task-oriented training and proceduralized technical manuals.

1. These are, in fact, logistic alternatives and may be reflected in requirements and cost estimates. All designs considered during the validation phase were assessed for the conventional approach. Additionally, the two-man flight deck avionics and landing gear were also assessed for the task-oriented approach. The technique used to reflect these different approaches was successful and could be used to consider other logistic alternatives in such areas as support equipment or spares.

2. The results quantifying the impact of the conventional and task-oriented approach for both the two-man flight deck avionics and the landing gear have proved a very useful input to the "Integrated Personnel, Training, and Technical Manual Section" of an Integrated Logistic Support Plan. A sample is included in the Appendix A to this report (Volume II).

3. A technique also has been developed to estimate the relative need for and extent of information coverage in both training and technical manuals. This estimate is developed for the specific personnel, training, and technical manual approach under consideration and is presented in a training/aiding matrix. This matrix is developed in the earlier

phases of acquisition before an "on-equipment" task analysis has been accomplished. Its purpose is to support early training/tech manual program definition and prioritization of requirements.

C. A single, evolving consolidated data base to service the requirements of all five technologies, as implemented, extended, and enhanced by CHRT, was established in the conceptual phase for the AMST avionics and landing gear. It was maintained and extended during the validation (prototype) and will be used to initiate the full-scale development (minimum engineering development phase).

PREFACE

This study was performed by Dynamics Research Corporation, 60 Concord Street, Wilmington, Massachusetts. Technical direction was provided by the Advanced Systems Division, Air Force Human Resources Laboratory (AFHRL), Wright-Patterson Air Force Base, Ohio.

The AFHRL support was provided under project 1959, Advanced Systems for Human Resources Support of Weapon Systems Development, Lieutenant Colonel John Adams, Project Director, and work unit 1959-00-02, Integration and Application of Human Resource Technologies in Weapon System Design, Dr. William B. Askren, Work Unit Scientist.

The Advanced Systems Department staff at Dynamics Research Corporation performed the research under contract F33615-77-C-0016 with Mr. Gerard F. King as Principal Investigator.

Many individuals throughout the Department of Defense and industry contributed their ideas and opinions to this effort. Of special note, however, were the members of the AFHRL Advanced Systems Division who contributed both in their specific areas of expertise and in the total development of CHRT. These individuals and their areas of expertise are Mr. Robert N. Deem, maintenance manpower modeling; Dr. Garry A. Klein, instructional system development; Dr. Donald L. Thomas, job guide development; Mr. Harry A. Baran, system ownership costing; and Dr. Lawrence E. Reed, consolidated data base. Major Robert J. Pucik of the AMST Program Office provided the interface with the AMST acquisition effort. Appreciation is also extended to Dr. John P. Foley, Jr., for sharing his view of job guide development and the instructional system/job guide relationship. Man-Tech Incorporated under subcontract to DRC provided significant assistance in the development of the training and technical manual concepts and products.

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I. INTRODUCTION

1.1 BACKGROUND AND PURPOSE

The Advanced Systems Division of the Air Force Human Resources Laboratory (AFHRL) has initiated a two-phase effort to integrate and apply five human resource technologies to the weapon system acquisition process as the coordinated human resource technology (CHRT). Phase I, the integration of these technologies and the development of CHRT, is complete and is documented in AFHRL-TR-78-6, Volumes I, II and III. Phase II, the application of CHRT in a weapon system acquisition program is being performed in three parts: Part 1, using conceptual phase data; Part 2, using validation phase data; and Part 3, using full scale development phase data. Parts 1 and 2 are complete. Part 3 is in progress.

This report describes the results to date of Parts 1 and 2 of the CHRT demonstration on the Advanced Medium STOL[2] Transport (AMST) acquisition program. The purpose of the demonstration is to validate the CHRT concept and its application in each phase of acquisition. The results of this demonstration will be utilized to refine and update the CHRT concept and consolidated data base (CDB) specification and to develop implementing documentation for CHRT and CDB in-service application.

1.2 COORDINATED HUMAN RESOURCE TECHNOLOGY CONCEPT

CHRT provides a method to predict and quantify the human resources (HR) and system ownership costs (SOC) associated with a weapon system. CHRT also provides a technique to implement an integrated consideration of the personnel, training, and technical manuals required to support the weapon system. Knowledge of HR and SOC requirements

[2] short takeoff and landing

facilitate identification and selection of these system and support design approaches which reduce and/or more effectively utilize human resources and which reduce SOC. The implementation of an integrated consideration of the personnel, training and technical manuals required to support the weapon system helps to achieve these efficiencies. The expression system and support design is used often in this total study. In clarification, the term system refers to the weapon system hardware and software. The term support refers to the weapon system integrated logistic support elements.

The Coordinated Human Resource Technology represents an integration of the five human resource technologies:

- Maintenance Manpower Modeling (MMM) - a method for estimating the maintenance manpower requirements for aircraft systems. This technology uses the Logistic Composite Model (LCOM) to simulate the maintenance system.

- Instructional System Development (ISD) - a methodology described in AFM 50-2 for qualifying personnel to perform tasks through an optimized training program.

- Job Guide Development (JGD)[3] - a method of developing a broad range of troubleshooting (TS) and non-troubleshooting (NTS) technical manuals designed to reduce training time and/or skill required to perform a task. These technical manuals are an alternate and/or supplement to ISD as a means for qualifying personnel.

- System Ownership Cost (SOC) - a systematic method of estimating operating and support costs and identifying major cost contributors.

- Human Resources in Design Trade-Offs (HRDT) - an approach utilizing the design option decision tree (DODT) for identifying system and support design trade-offs, so that the human resource impact of the critical alternatives at those decision points may be determined.

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[3] The term job guide and technical manual are used to express the same concept. Technical manual is the preferred term, however, and will be used in describing new work.

The development of CHRT from the individual technologies and the structure of the CDB from which CHRT operates are fully described in AFHRL-TR-78-6 (I, II and III). That report documents a 7 month development effort and is synopsized as follows:

Traditionally, the five technologies have been applied independently, at various discrete times and generally late during the weapon system acquistion process. Their application and contribution may be summarized as follows:

- MMM has been applied to various aircraft systems during the validation and full-scale development phases in order to predict system maintenance manpower requirements using the LCOM simulation.

- ISD as a decision-making process is applied late in the validation phase to define the ISD program and also theoretically to define the applicability of job guide documentation. This latter determination, when accomplished, is the sole coordinated ISD/JGD activity. ISD as a product-oriented process then continues through full-scale development into production/deployment.

- JGD is initiated in full-scale development as a product-oriented effort. During the course of its associated task analysis, a reconsideration of the training/support equipment/job guide mix may be made.

- SOC is not presently a rigorous technology but rather a Defense Systems Acquisition Review Council (DSARC) milestone requirement. It is normally responded to with a point cost estimate. Equations and models for obtaining these estimates are not standardized nor do the sources of data always adequately reflect the system being costed.

- HRDT exists as the DODT technique and as a concept of using HR data in design trade-offs. It can be applied at many levels of detail throughout system acquisition. There is, however, no standardized technique for interfacing with the other technologies to obtain the HR or SOC data associated with the design alternatives.

Figure 1 depicts the above summary of the traditional application of the five human resource technologies during weapon system acquisition.

There are recognized similarities in activities and data requirements among the five technologies. AFHRL-TR-78-6 (I, II, and III) explores these similarities and describes the potential for expanded and integrated application of the technologies. This potential application is depicted in Figure 2:

- MMM is initiated in the conceptual phase. A generalized maintenance task analysis is performed based on comparative system historical data and maintenance action networks are developed. The average value method devised for the Digital Avionics Information System (DAIS) Life Cycle Cost (LCC) Study, the Reliability and Maintainability (R&M) model, is used to investigate maintenance manpower requirements, as well as, reliability and maintainability data. Reliability and maintainability directly affect human resource, logistics, and cost requirements. These results are directly reflected in the SOC estimate and are usable for DSARC I. The maintenance task analysis information and the maintenance manpower requirements are both used as input data to the ISD/JGD decision process.

- MMM is updated in the validation phase through a review of the generalized maintenance task analysis data and maintenance action networks. Maintenance manpower requirements are again investigated using the R&M model. The LCOM simulation is used only to refine maintenance manpower requirements for systems or subsystems of significant interest. Reliability and maintainability data are updated. The results are reflected in the SOC estimate usable for DSARC II. The general maintenance task data and the maintenance manpower requirements determined at this time continue to be used as input to the ISD/JGD decision process.

- MMM is updated in the full-scale development phase by replacing the general maintenance task data with that derived from the initial steps of an ISD/JGD integrated task

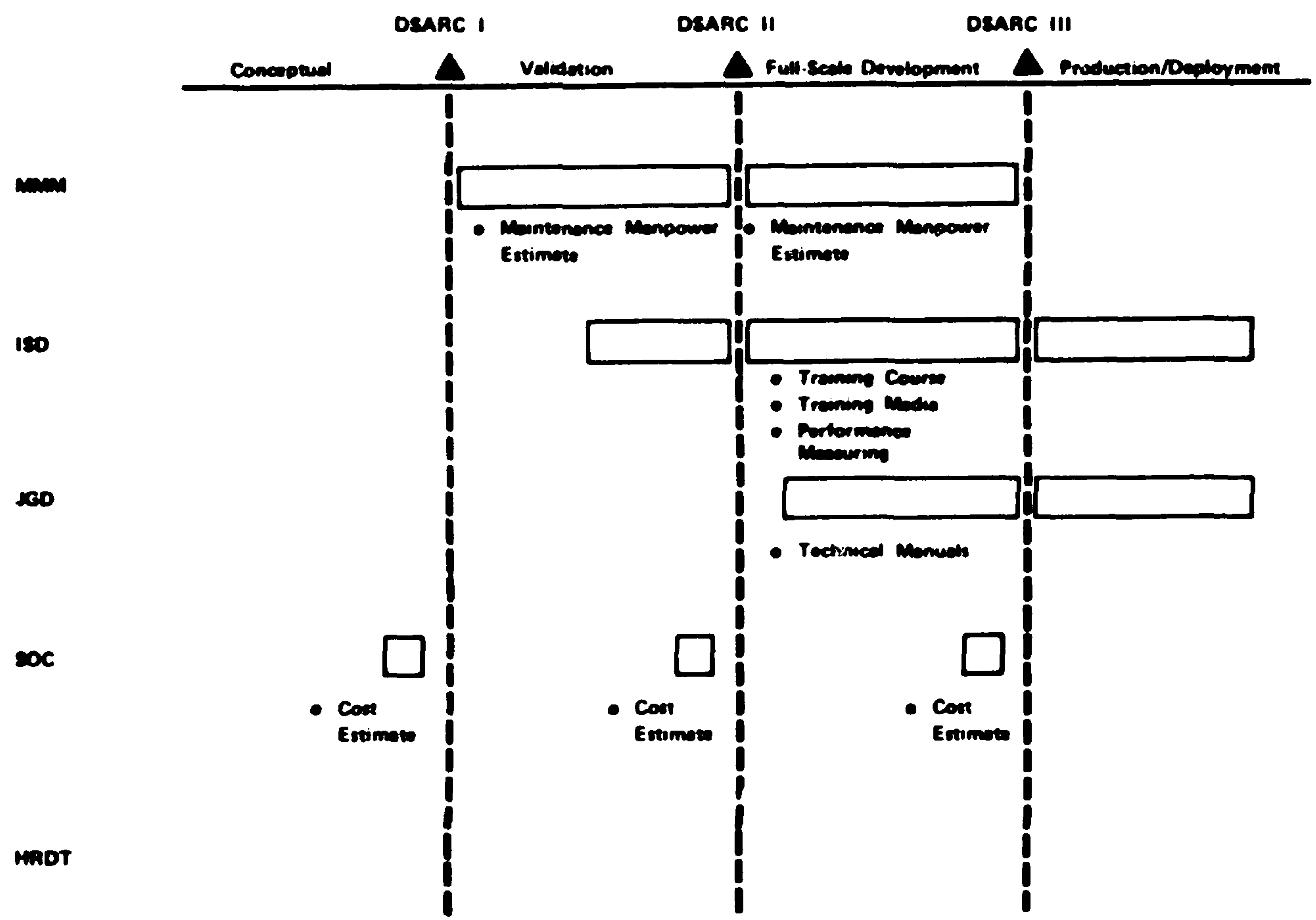


Figure 1 PRESENT HUMAN RESOURCES TECHNOLOGY APPLICATION

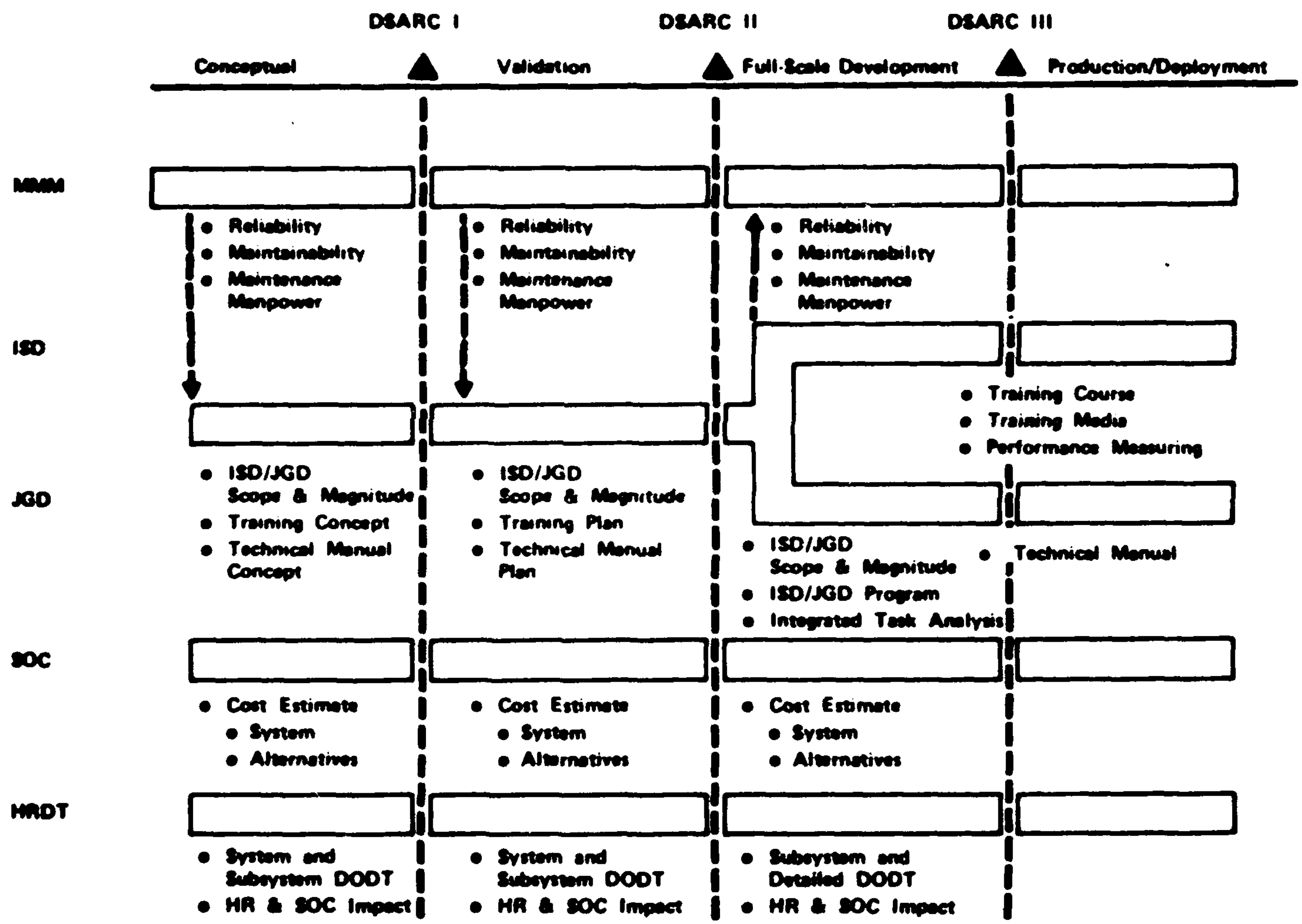


Figure 2 PROPOSED HUMAN RESOURCES TECHNOLOGY APPLICATION

analysis. LCOM is used to confirm earlier predictions of maintenance manpower requirements. Reliability and maintainability data derived throug the R&M model are required for use with the SOC model. Maintenance manpower requirements are fedback to ISD/JGD integrated task analysis.

- The ISD/JGD decision process is initiated in the conceptual phase and continued during the validation phase to continually refine the ISD/JGD requirement. The training and technical manual requirement again is reflected in the SOC estimates for both DSARC I and II and in the training and technical manual plans.

- A single integrated task analysis on the actual system is initiated during full-scale development. This analysis is used to define the training/technical manual trade-off and subsequently for training and technical manual development.

- Operational manpower requirements and the necessary ISD to support this manpower requirement in each phase is determined. These data are needed to supplement the data provided by the five technologies.

- A single LCC model which can be applied with continuity through all acquisition phases is used. This model is interactive with the R&M model and is especially sensitive to SOC.

- HRDT is incorporated in all phases. This technology provides a feedback loop to the others and allows:

    - Assessment of existing designs to identify areas requiring excessive human resources or funding. In addition to drawing attention to these "high drivers", the assessment will identify potential solutions to the identified problem area.

- Evaluation of alternative system and support design approaches in terms of the human resources considerations and operating and support costs. The human resource requirements and associated cost implications would then be used as part of the decision-making process in selecting an appropriate alternative.

- All significant data required to support the five individual technologies are consolidated in a single data base, the CDB. The content of the CDB, as conceptually described by AFHRL-TR-78-6 (III), is depicted in Figure 3.

The concept of the maintenance action network as a means of modeling the maintenance system is critical to the application of the CHRT. To ensure a basic understanding, a very brief description of the maintenance action network as used with the R&M model is provided in the next paragraph. A more complete description is included in AFHRL-TR-78-2.

The generalized maintenance action network depicted in Figure 4 represents the types of flight line and shop maintenance anticipated in an aircraft system. Each branch of this network, with the exception of subsystem failure, is annotated with probability of occurrence, time to complete action, maintenance personnel characteristics (skills, levels, and numbers) and support equipment requirements. Subsystem failure is only annotated with probability of occurrence. The R&M model operates on these networks and provides average values for maintenance manpower requirements and mean time to repair at the subsystem level for the flight line and at the line replaceable unit (LRU) level for shop. The data used to annotate these networks in the early acquisition phases are developed from an analysis of historical data on comparable equipment. This analysis must judgmentally consider the source of the historical data and the intended application of the proposed system. These data are gradually replaced with actual subsystem data as the subsystem hardware is built and used data are collected. The networks, therefore, grow from an estimated to an actual model of the maintenance system.

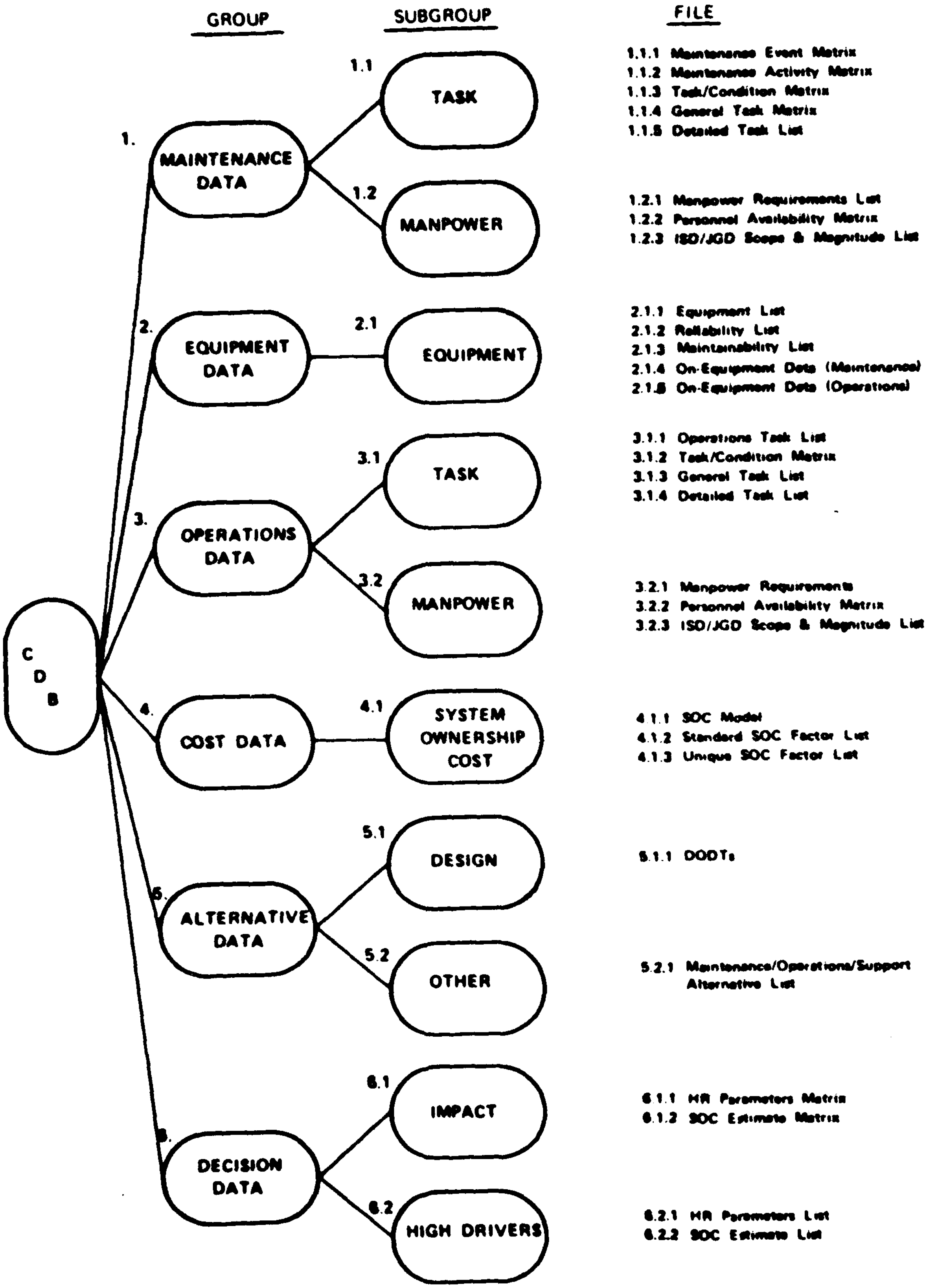
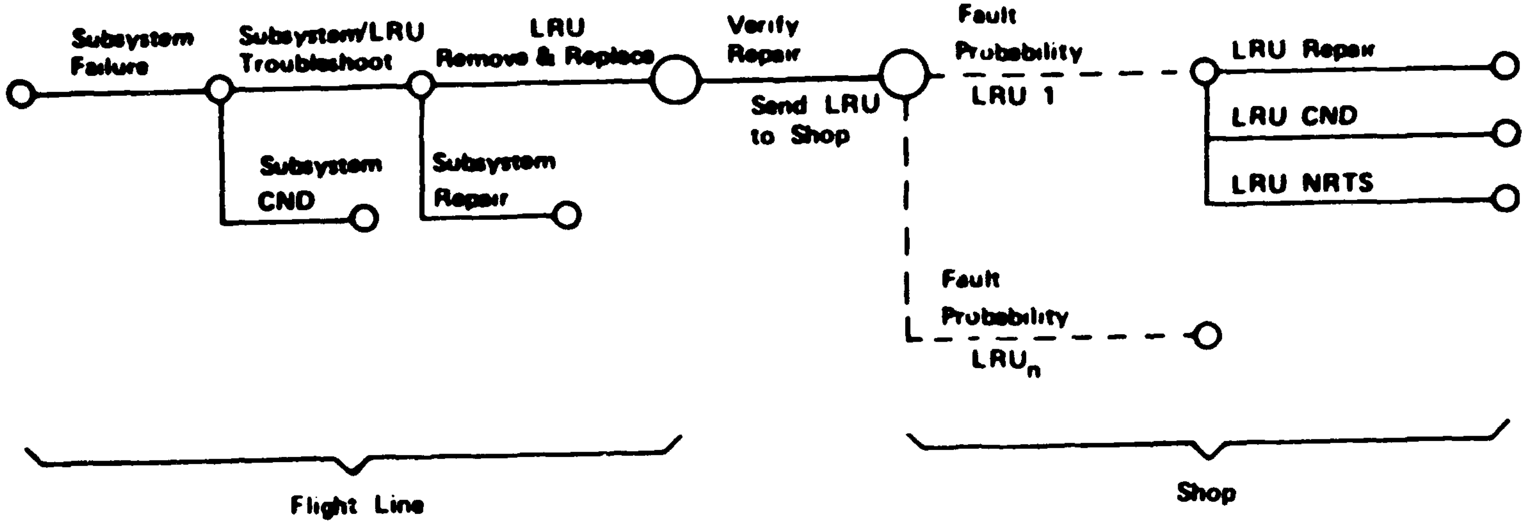


Figure 3 CDB STRUCTURE



LRU - line replaceable unit
CND - cannot duplicate
NRTS - not repairable this station

Figure 4 GENERALIZED MAINTENANCE ACTION NETWORK

1.3 CHRT AND THE WEAPON SYSTEM LIFE CYCLE

CHRT is applied iteratively across all phases of the weapon system life cycle. On any one weapon system, it provides continuity of both source and rationale for HR and SOC data. The source is a CDB which is initiated in the conceptual phase and updated in accuracy and detail as acquisition proceeds. Comparable systems information is used to establish and maintain the CDB until actual system information is available usually during full-scale development.

The HR and SOC information is derived from the CDB and, therefore, is directly dependent for accuracy and level of detail on the CDB. The rationale or methodology for developing the HR and SOC data remains basically unchanged throughout acquisition. The HR data which CHRT predicts and quantifies are operations and maintenance manpower requirements (quantity, skills, and skill levels), training course length (time), and technical manual content (number and type of pages). Additionally, CHRT predicts and quantifies reliability (MFHBMA)[4] and maintainability (MTTR)[5]. These latter data are useful directly and are also required for SOC computation. SOC is that portion of LCC consisting of the non-recurring support investment and the recurring operating and support costs. The availability of this human resource related data in turn facilitates the assessment of baseline(s) and alternative(s) and the identification of "high drivers." Throughout, training and technical manuals are addressed as a coordinated pair and are considered as either conventional or task-oriented in nature. The conventional approach emphasizes broad based training in theory and system operation which is supported in the field by deductive technical manuals. The task-oriented approach emphasizes "hands on" training in key tasks which is supported in the field by directive technical manuals. Additional predictive information is available through the DODTs which depict potential design decision points and available alternatives.

CHRT makes use of three logistic resource assessment models developed by AFHRL: the R&M model, LCOM, and the Expected Value (EXPVAL) model. The latter is an average value model developed for use with LCOM. An LCC model directly driven by the maintenance system represented by and the results of the R&M model provides SOC.

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[4]MFHBMA - mean flight hours between maintenance actions
[5]MTTR - mean time to repair

Conceptual Phase

A CDB is established in the conceptual phase for each system configuration under consideration. Each system configuration is termed a baseline and includes a tentative maintenance/personnel/training/job guide approach. HR and SOC data are developed for each baseline and are used to help determine which baseline(s) will be continued for consideration in the validation phase. The accuracy and level of detail of the HR and SOC information are adequate to support system level decisions and may be used to identify risk areas. An integrated personnel/training/technical manual concept is developed.

Validation Phase

The CDB is updated for each baseline retained for validation phase consideration. More detailed comparability information may be used because the baseline may now be described in more detail. Alternatives within each baseline are also identified and the CDB is extended to include those alternatives that require consideration. HR and SOC data are prepared for each baseline and reiterated within a baseline for each alternative. The accuracy and level of detail of the HR and SOC information at this stage is sufficient to support both system and subsystem decisions and may be used to quantify risk areas at the same level. An integrated/personnel/training/technical manual plan is developed.

Full-Scale Development Phase

Normally one baseline is carried into full-scale development. However, many alternatives may be identified within this baseline. The CDB is updated during this phase with actual system data for the baseline, and with comparable or actual system data for those alternatives under consideration. HR and SOC data are then prepared and may now be used to support system, subsystem, and detailed level decisions and to verify reduction of risk areas. During this phase a task identification matrix is developed which identifies the maintenance tasks required to be performed on specific equipments. It also identifies the level of maintenance at which these tasks are to be performed. As such the task identification matrix reflects the maintenance concept. The task identification matrix is then annotated to indicate where instruction to accomplish these tasks will be provided. Training, technical manuals, or both are the options available. Rules for annotating the task identification matrix are developed from the personnel/training/technical manual plan and directly reflect the personnel skills and levels desired and qualification approach required. This annotated task identification matrix then forms the basis for the training and technical manual procurement.

Production/Development and Operations Phase

In the production/deployment and operations phase the CDB is updated with new and more current actual system data for the production baseline. Alternatives may now be identified in terms of proposed engineering changes and even new applications to meet contingency requirements. The CDB is extended to include any alternative to be considered and HR and SOC information are generated as required. These data may now be used to support the user, in-service engineering, and logistics. The data also may be used to verify that previously identified risk areas have been eliminated, and/or to identify new risk areas. A coordinated training and technical manual program is implemented to support the operation and maintenance of the production system.

1.4 CHRT PROCESS

The elements of the human resource technologies and their proposed coordinated application in the conceptual and validation phases are depicted in Figure 5 as the CHRT process. AFHRL-TR-78-6(II) contains a detailed description of this process and a companion figure depicting the CHRT process in the full-scale development phase. The following comments are provided as a summary of the concept depicted by Figure 5:

- The process is shown as a function flow diagram. It is structured in a systematic manner which lends itself to computerization.

- The CDB consists of all equipment, task, maintenance, operations, personnel, and cost data elements stored in matrices and listings. The CDB contains all information necessary to apply CHRT.

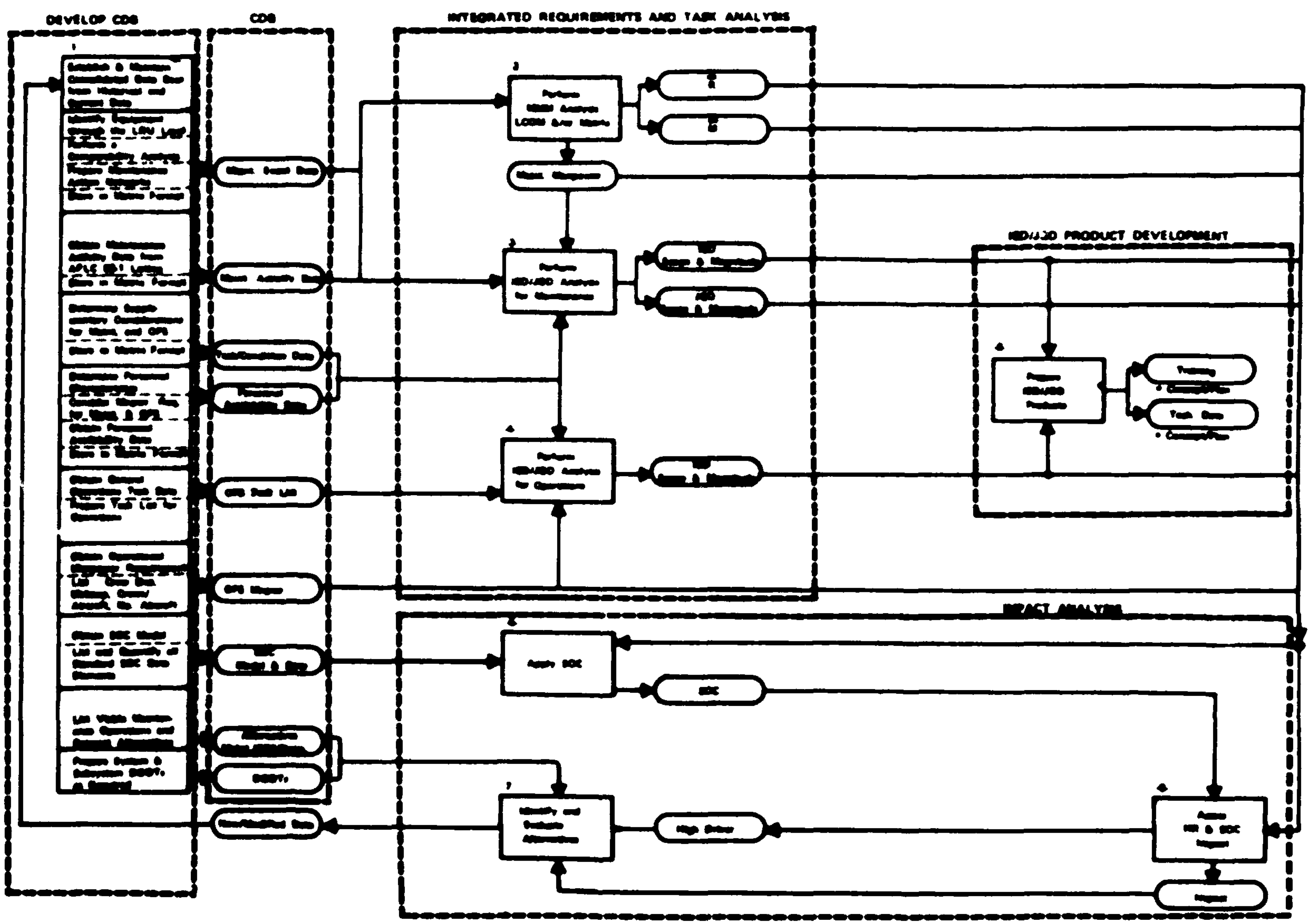


Figure 5 THE CHRT PROCESS (CONCEPTUAL AND VALIDATION PHASES)

- Input data covers design, maintenance, operations, support and cost. The source and validity of this data will vary from phase to phase.

- Output data includes reliability, maintainability, maintenance manpower requirements, training and technical manual scope and content, training scope for operations, and a system ownership cost estimate.

- The CHRT process has been subdivided into four main activities which are indicated by dotted lines:

  - CDB Development
  - Integrated Requirements and Task Analysis
  - ISD/JGD Product Development
  - Impact Analysis

- The scope of the integrated requirements and task analysis expands with time during the weapon system acquisition process. It processes all the task data necessary for prediction and definition of the human resource requirements, as well as that required to prepare the ISD/JGD products.

- The impact analysis results in comparative human resources and cost data for baseline(s) and alternative(s). It can be accomplished at any equipment level (i.e., system, subsystem, or LRU). The SOC model provides the means of translating human resource data to cost data on both a system and a subsystem basis.

- The product development activity utilizes an integrated approach to training and job guide development. It provides the concepts, plans, and programs.

Although the CHRT process appears very complex when described in terms of the individual technologies of which it is composed, it is, in reality, a very straightforward procedure when viewed as a series of interrelated steps. This proceduralized approach is described in the following paragraphs, and is based upon the experiences gained from applying CHRT and its CDB to the conceptual and validation (prototype) phase data of the AMST.

The steps are described along with a marginal notation of the basic source technology. For example, HRDT indicates that the step was developed from activities within the HRDT technology. The notation NEW indicates a step unique to the CHRT process. The input data and output data of the step, both of which are described, make up the CDB. Steps are applicable to all phases unless otherwise indicated. Steps accomplished in one phase may simply require review and update in subsequent phases. The steps follow.

A. Prepare and review DODTs for critical trade-off issues involving system and subsystem equipment and logistics planning. HRDT

B. Determine baseline design, operation, maintenance, and support approach(es) and alternatives from data collected in A. HRDT

For each baseline and alternative:

C. Conduct a system comparability analysis. Prepare an equipment listing to the LRU level and identify comparable equipment if appropriate. Estimate or determine MFHBMA for subsystem or major equipment and the number of shop replaceable units (SRU) per each LRU. MMM

D. Prepare a maintenance action network and annotate each action with: MMM

(1) Air Force specialty code (AFSC), quantity, and skill level of maintenance personnel.

(2) Time and probability of occurrence.

(3) Support equipment required, setup, and use time.

(Note: annotations should reflect appropriate personnel/training/technical manual approach.)

E. Input data to the appropriate logistics resource assessment model. MMM

(1) Use the R&M model in all phases to obtain complete HR & SOC assessment.

(2) Use LCOM to evaluate maintenance manpower and support equipment requirements for baseline and prime alternatives. (LCOM considers the dynamics of the specific scenario being evaluated). Because of the resources required for this simulation, it would rarely be appropriate prior to the late validating phase.

(3) Use EXPVAL when only average values for maintenance manpower and support equipment requirements are desired. It may be applied in all phases as appropriate. It is also used as a debugging tool for LCOM.

F. Review DAIS R&M model output. Extract and/or determine as required.

(1) Per subsystem/major component/LRU/SRU:

- Availability $= \frac{\text{MFHBMA}}{\text{MFHBMA} + \text{MTTR}}$
- MFHBMA
- Flight line - troubleshooting time, maintain on aircraft time, remove and replace time, MTTR, and maintenance manhours per flying hour (MMH/FH).
- Shop - MTTR

(2) Maintenance Manpower requirements per AFSC and skill level in terms of:

- MMH/FH
- Manpower/squadron

(3) Support equipment requirements per unit in terms of:

- Support equipment hours per flying hour (SEH/FH)
- Quantity/squadron

G. Review LCOM output. Extract and/or determine: MMM

(1) Per Subsystem - Maintenance manpower requirements (hours) per AFSC and skill level.

- On-Equipment Maintenance
- Off-Equipment Maintenance

(2) Per Subsystem - Support equipment use (hours).

- On-Equipment Maintenance
- Off-Equipment Maintenance

H. Review EXPVAL output. Extract and/or determine: MMM

(1) Per Subsystem - Maintenance manpower requirements in (hours) per AFSC and skill level.

- On-Equipment Maintenance
- Off-Equipment Maintenance

(2) Per Subsystem - Support equipment use (hours).

- On-Equipment Maintenance
- Off-Equipment Maintenance

I. Determine operations manpower requirement by review of system documentation and calculate: NEW

- Crew composition, rank, and years of service
- Manpower/squadron skill

J. Prepare training estimates (time). NEW

(1) Per maintenance AFSC

- Identify training courses required
- Determine course length for conventional and/or task-oriented approach

(2) Per crew AFSC

- Identify crew training course
- Determine course length

K. Prepare technical manual estimates (number and type pages). NEW

(1) For Shop by Equipment

- Conventional only
- Troubleshooting/non-troubleshooting

(2) For Flightline by Equipment

- Conventional and/or task oriented
- Troubleshooting/non-troubleshooting

(Note: The task identification matrix may be used in the full-scale development and production phases as the basis for the final training and technical manual estimates).

L. Prepare training/technical manual trade-off definition matrices.

(1) Training/aiding matrix NEW

(2) Task identification matrices - full-scale development and production phases. JGD

Prepare the cost model for SOC calculation. NEW

(1) Select and/or update cost area equations.

(2) Update standard input values.

- Pay rates
- Personnel turnover
- Spares Pipeline time

(3) Determine unique input values.

- Crews/aircraft
- Number of aircraft
- Aircraft/squadron
- System force structure
- Flying hours/aircraft/day
- Cost/spare
- Support Equipment requirements
- Manpower profile

(4) Obtain acquisition and R&D cost data.

(5) Normalize all cost data to appropriate year.

Operate the LCC model and determine SOC. SOC

(1) Support investment cost (one time)

(2) O&S costs (annual)

Review and correlate HR and SOC data as appropriate to: NEW

(1) Present individual results

(2) Evaluate impact among baseline(s) and/or alternatives

(3) Identify risk and/or payoff areas

P. Reiterate process as required to: NEW

(1) Update HR and SOC estimates

(2) Consider additional alternatives

Q. Prepare ISD/JGD product appropriate to each phase for selected baseline(s). ISD/JDG

(1) Personnel/training/technical manual concept - conceptual phase

(2) Personnel/training/technical manual plan - validation phase

(3) ISD/JGD program definition - full-scale development phase

(4) ISD/JGD program - production phase

1.5 DEMONSTRATION OBJECTIVES AND GUIDELINES

The specific objectives of this demonstration are to:

A. Determine the feasibility of applying the CHRT and the CDB in all phases of weapon system acquisition.

B. Identify, provide, and evaluate the utility of the CHRT products.

C. Determine the content and effectiveness of a CDB.

D. Identify and correct inadequacies and/or inconsistencies in the CHRT process and the CDB.

E. Estimate the resources required to apply CHRT with a CDB versus the five individual technologies with individual data bases.

All the above objectives will be addressed in this report except E. Upon completion of the total demonstration, personnel records will be reviewed to determine resources required to apply CHRT and to develop and maintain a CDB. This information will then be included in the final CHRT report.

The guidelines imposed on the demonstration are to apply CHRT on the avionics and landing gear systems of the AMST and to adapt the CHRT demonstration to the AMST program. Since both the conceptual and validation (prototype) phases of the AMST program were complete when this demonstration was initiated, it was necessary to simulate the application of CHRT in those phases. Actual historical data from the conceptual and prototype phases of the AMST program were used for this purpose. It was important to limit the demonstration to typically available data in order to draw meaningful conclusions about CHRT applicability throughout the acquisition cycle. The demonstration of CHRT during the AMST full-scale development (minimum engineering development) phase will also be simulated since that actual activity is, at present, indefinitely delayed. Typical data will be projected.

II. DEMONSTRATION IN THE CONCEPTUAL PHASE

2.1 OVERVIEW

The demonstration of CHRT as applied in the conceptual phase was conducted during the three month period 16 October 1977 to 15 January 1978. AMST conceptual phase data were the prime source of information. HR and SOC data were developed on four baselines, two for avionics and two for landing gear.

The results indicated that the conceptual phase application of the CHRT process and CDB was feasible. Only actual conceptual phase source data supplemented with data that could have been obtained in the conceptual phase was used and proved adequate to support CHRT and the development of HR and SOC estimates. These estimates, the CHRT conceptual phase products, were reviewed and evaluated. It was concluded that these products could provide significant assistance to an acquisition manager in evaluating alternative design, operations, maintenance, and support approaches. The HR and SOC estimates covered broader scope and provided more detail than usually available at this stage of acquisition. These data, derived through application of a rigorous and rational methodology, reflected the interrelationships among operations, maintenance, and logistics. The content of the CDB as described in the functional specification, AFHRL-TR-78-6(III), was adequate and effective with minor modification. The SOC model and the technique used to reflect an integrated approach to personnel, training, and technical manuals were identified as areas for improvements which were then initiated during the validation phase demonstration.

2.2 THE AMST CONCEPTUAL PHASE AND DATA SOURCES

The AMST conceptual phase occurred in the 1972 time frame. Three contractors--McDonnel Douglas, Lockheed-Georgia, and North American Rockwell--participated and eventually submitted conceptual studies covering a total of eight airframe, engine, and high lift combinations. Prior to the completion of the studies, however, the Air Force received Department of Defense direction to accelerate efforts and to immediately initiate a prototype procurement. As a result, the conceptual phase studies were empleted but delivered after the prototype phase began and the studies were not evaluated. These conceptual studies were retrieved and used for this demonstration. Coupled with the appropriate version of the Requirement for Operational Capability (ROC), they provide a significant portion of the conceptual phase data required.

CHRT also require the development of maintenance action networks in the conceptual phase through a comparability analysis. Since the AMST conceptual phase took place before any requirement for maintenance action networks was established, these data were not directly available. A generalized AMST maintenance action network had been developed in the early prototype phase, however. This network was used during the demonstration as conceptual phase data. This action was justified because a review of the conceptual studies indicated that comparability was well enough defined by those studies to have developed a generalized network at that time.

2.3 CHRT RESULTS - CONCEPTUAL PHASE

The results of the CHRT demonstration are presented and discussed under the following topics:

- Baseline(s) and alternative(s)
- Reliability, maintainability, and maintenance manpower requirements
- Operations manpower requirements
- Scope and magnitude of training and technical manuals for maintenance personnel
- Scope of training for operations personnel
- SOC
- HR and SOC impact of baseline(s) and alternative(s)
- High drivers
- Training and technical manual products

Data developed were based on an assumed 300 aircraft: 256 unit equipped (UE) and 44 not operationally available (NOA). It was also assumed that there would be 16 squadrons and one training squadron of 16 aircraft each, divided among four Continental United States (CONUS) and two overseas locations. Aircrew/aircraft ratio per UE and per NOA used for training is 2:1. Utilization rate is 1.5 hours/day during a 5 day week. Samples of data will be included in the discussion. itself when appropriate. A data supplement is provided under separate cover as Appendix A (Volume II).

Baseline(s) and Alternative(s)

Potential baselines and alternatives for equipment configuration, engineering design, and operations, maintenance, and support approaches are documented in CHRT by DODTs and alternative listings. The alternative listing contains information not directly documented by a DODT such as payload or takeoff field length. The information required to develop this documentation is obtained from designers, engineering data, program direction, specifications, and standards. The AMST conceptual phase proposals and the ROC provided the primary source data in this case along with an equipment listing from the original AMST comparability analysis.

Twelve (12) DODTs were developed: one for the AMST system, eight for avionics, and three for landing gear. The AMST system DODT is presented in Figure 6. A major alternative directly affecting system design, avionics design, and operations manpower requirements was immediately discernable from the system DODT as well as the alternative listing. This alternative is the three-man versus four-man crew option (i.e., pilot, copilot, and loadmaster without and with a navigator). A more intensive review of all the DODTs resulted in the identification of four baseline configurations for consideration.

- Two-man flight deck (2MFD) avionics (pilot and copilot)
- Three-man flight deck (3MFD) avionics (pilot, copilot, and navigator)
- Modified C-141 landing gear
- New landing gear

The significant difference between the 2MFD and 3MFD avionics is the inclusion of processors, control integration, unique displays, and integrated instruments in the 2MFD version. Portions of the avionics DODTs which display these differences are shown in Figure 7. These trees are annotated 2MFD and/or 3MFD to indicate the appropriateness of the decision block to the design option. Unannotated blocks indicate that they are appropriate to either option.

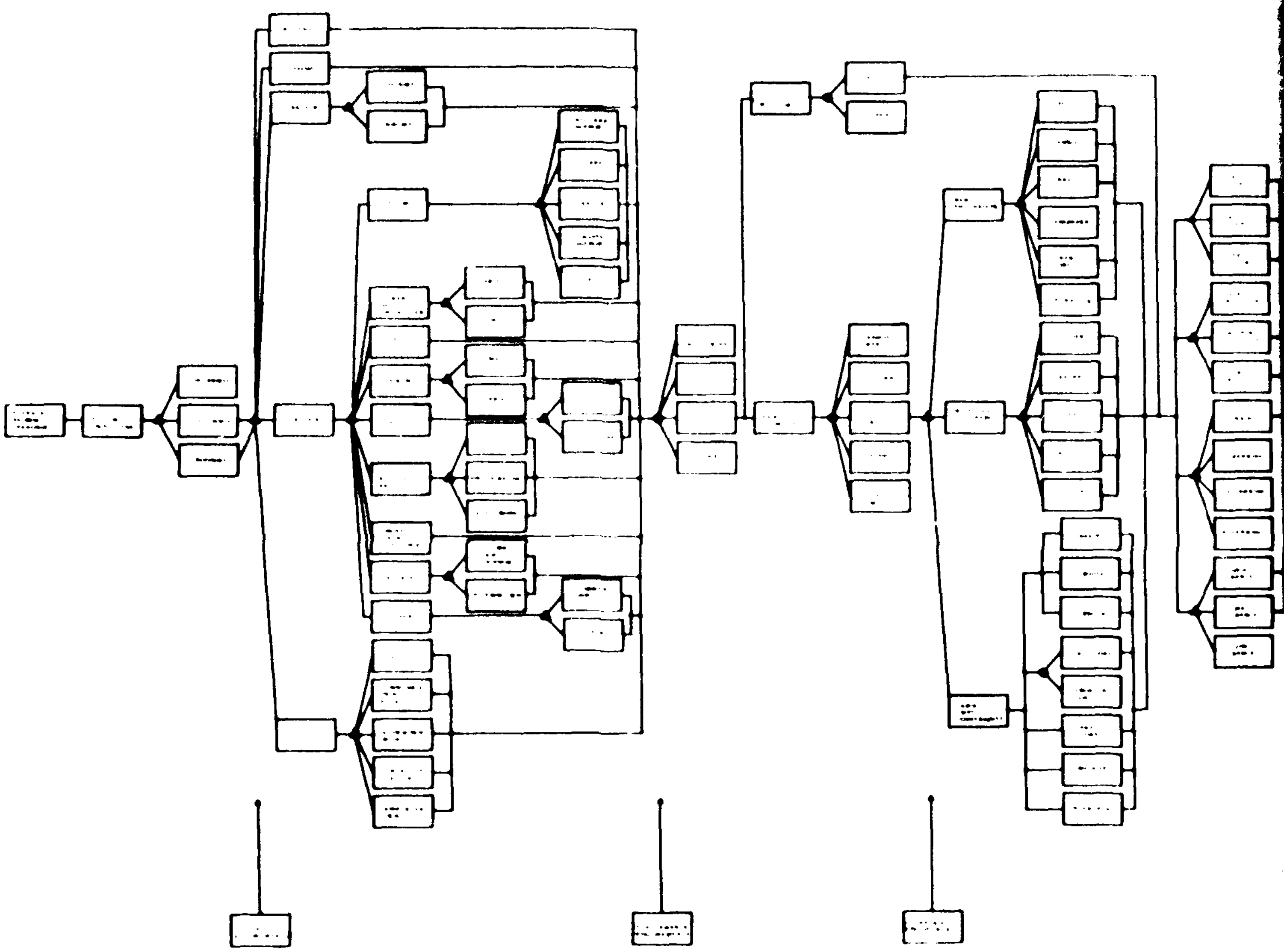
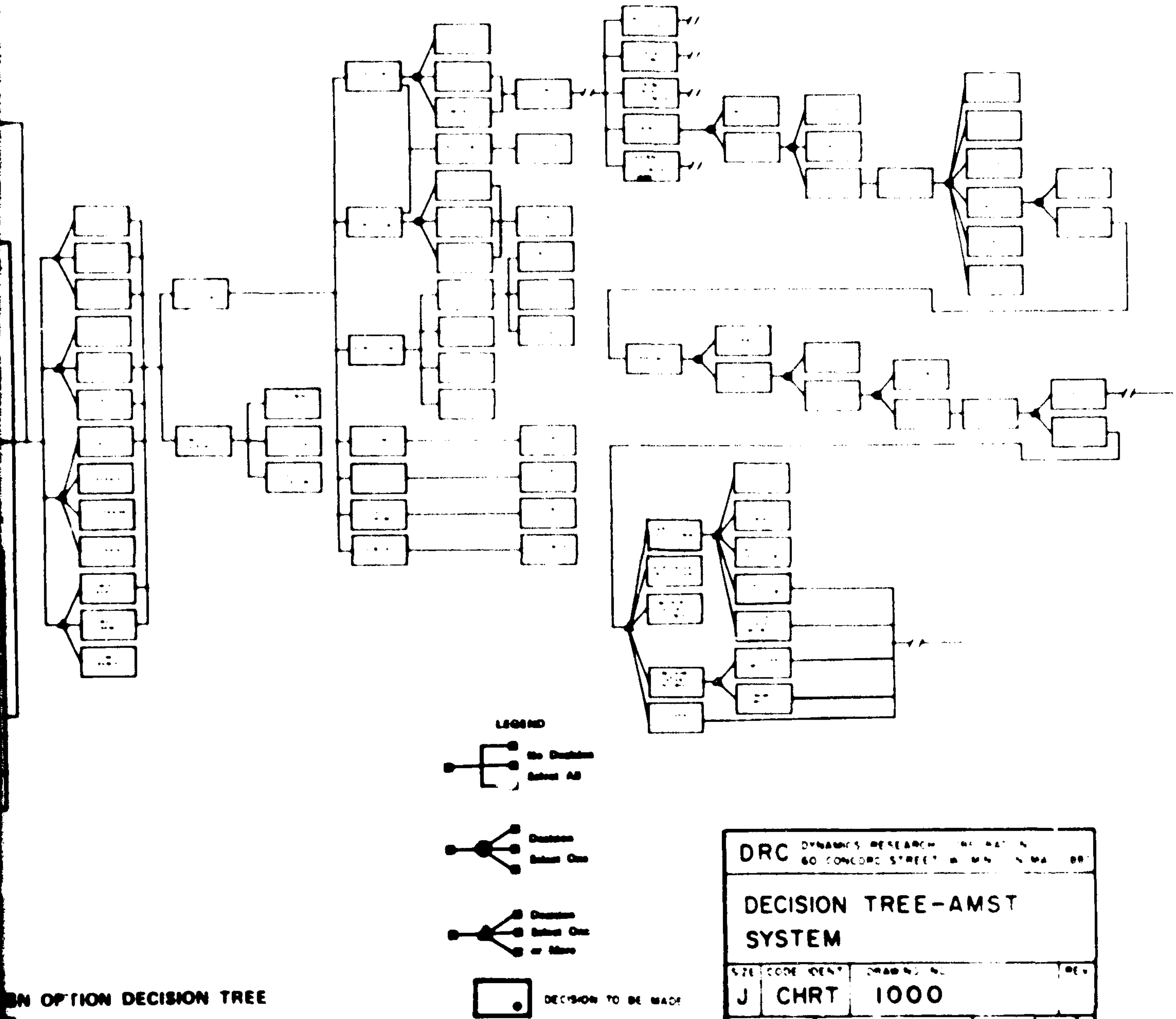


Figure 6 AMST SYSTEM DESIGN OPTION DE
(CONCEPTUAL PHASE

1



N OPTION DECISION TREE

DRC DYNAMICS RESEARCH CORPORATION 60 CONCORD STREET			
DECISION TREE-AMST SYSTEM			
SIZE	CODE IDENT	DRAWING NO.	REV
J	CHRT	1000	
SCALE NONE		SHEET	OF

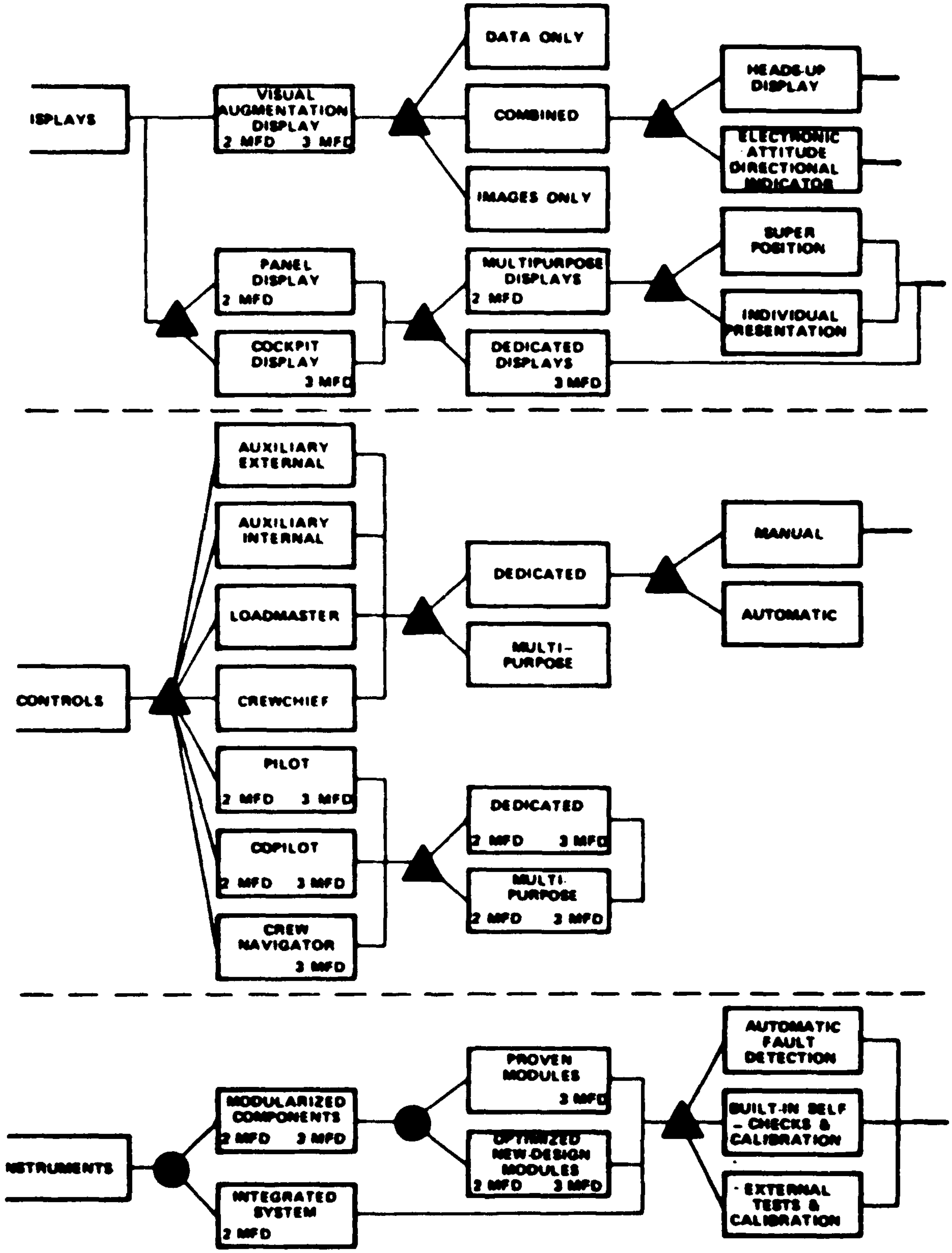


Figure 7 AVIONICS OPTIONS

A modified C-141 landing gear offered commonality and thus reduced support requirements over a new landing gear. Technically, both landing gear are considered comparable at this phase of design and no significant design differences are noted. Therefore, only one equipment configuration was analyzed.

A listing of the DODTs developed and the alternative listing is provided in Appendix A (Volume II). A complete set will be provided with the report documenting the demonstration of CHRT and the CDB in full-scale development.

Reliability(R), Maintainability(M), and Maintenance Manpower Requirements

The generalized AMST maintenance action networks obtained from the AMST System Program Office (SPO) covered the baseline configurations identified in the DODT analyses. These networks were reviewed for completeness and validity. They were then used as input data for the R&M model (AFHRL-TR-78-2). The model was then operated and reliability, maintainability, and maintenance manpower data were obtained for each configuration. The reliability and maintainability results calculated for the 3MFD avionics and 2MFD avionics are presented in Tables 1 and 2 respectively. The first three columns of Tables 1 and 2 represent the CHRT equipment codes, the comparable aircraft systems, and the major item descriptors. Some common abbreviations used with the major item descriptors are:

HF	high frequency
VHF	very high frequency
FM	frequency modulation
AM	amplitude modulation
UHF	ultra high frequency
DF	direction finder
IFF	interrogator friend or foe
TACAN	tactical air navigation system
VOR	visual omni range
ILS	instrument landing system
LF	low frequency
SKE	station keeping equipment
INS	inertial navigation system
HUD	heads up display
CRT	cathode ray tube

The remaining columns provide measures of reliability and maintainability which are:

Availability - calculated as $\frac{\text{MFHBMA}}{\text{MFHBMA + MTTR}}$

MFHBMA - man flight hours between maintenance actions

R&R - mean remove and replace time on the flight line (hours)

Code	Comparable System	Item	Availability	MFHBMA	R&R	MTTR	MMH	MMR
FAC110	(FB111)	HF Radio (2)	.47	4	2.62	4.56	13.66	3
DAC210	(C130E)	VHF/FM Radio	.994	200	.94	1.26	3.80	3
GAC220	(C141)	VHF/AM Radio	.92	24	.74	2.12	6.36	3
CAC320	(C5)	UHF Radio (2)	.91	27	1.04	2.67	8.01	3
DAC330	(C130)	UHF-DF	.99	800	.17	1.33	5.16	3.0
DAC410	(C130E)	Intercom	.86	4	.56	2.04	6.12	3
DAC420	(C130)	Public Address	.99	306	.86	3.80	12.86	3.4
DAC510	(C130)	IFF	.98	200	1.01	3.09	9.40	3.0
BAC520	(B52G)	IFF Computer	.90	36	.70	3.90	11.70	3.0
BAC620	–	Secure Voice	.99	840	1.40	3.70	11.10	3
CAC710	–	Crash Position	.96	47	0.91	2.30	9.58	4.0
FAN120	(FB111)	TACAN	.99	164	1.78	2.16	6.5	3.0
GAN130	(C141)	VOR/ILS (2)	.96	33	0.70	1.87	5.6	3.0
GAN140	(C141)	LF-DF	.91	32	1.51	3.19	9.57	3.0
AAN210	(A7D)	Radar Altimeter (2)	.99	187	1.23	2.36	7.06	3.0
CAN230	(C5)	Omega	.89	29	1.38	3.62	10.86	3.0
EAN240	(C135)	Radar	.52	4	1.73	3.42	12.81	3.8
DAN250	(C130E)	SKE	.75	9	1.26	2.98	9.98	3.3
TAN330	(T43)	INS	.89	18	.88	2.19	6.56	3.0
AAN350	(A7D)	Micro HUD	.94	56	1.42	3.36	10.09	3.0

Table 1 R&M SUMMARY – 3 MAN FLIGHT DECK AVIONICS

Code	Comparable System	Item	Availability	MFHBMA	R&R	MTTR	MMH	MMR
FAC110	(FB111)	HF Radio (2)	.52	5	2.62	4.56	13.66	3
DAC210	(C130E)	VHF/FM Radio	.996	400	.94	1.26	3.80	3
GAC220	(C141)	VHF/AM Radio	.96	52	.74	2.12	6.36	3
CAC320	(C5)	UHF Radio (2)	.97	37	1.04	2.67	8.01	3
DAC330	(C130)	UHF-DF	.99	800	.17	1.33	5.16	3.0
DAC410	(C130E)	Intercom	.86	4	.56	2.04	6.12	3
DAC420	(C130)	Public Address	.99	306	.86	3.80	12.56	3.4
DAC510	(C130)	IFF	.98	200	1.01	3.09	9.40	3.0
BAC520	(B52G)	IFF Computer	.90	36	.70	3.90	11.70	3.0
BAC620	–	Secure Voice	.99	840	1.40	3.70	11.10	3
CAC710	–	Crash Position	.96	47	0.91	2.30	9.58	4.0
FAN120	(FB111)	TACAN	.99	164	1.78	2.16	6.5	3.0
GAN130	(C141)	VOR/ILS (2)	.96	38	0.70	1.87	5.6	3.0
GAN140	(C141)	LF-DF	.96	62	1.51	3.19	9.57	3.0
AAN210	(A7D)	Radar Altimeter (2)	.99	187	1.23	2.36	7.06	3.0
CAN230	(C5)	Omega	.89	29	1.38	3.62	10.86	3.0
EAN240	(C135)	Radar	.62	6	1.73	3.42	12.81	3.8
DAN250	(C130E)	SKE	.78	11	1.26	2.98	9.98	3.3
TAN330	(T43)	INS	.90	22	.88	2.19	6.56	3.0
AAN380	(A7D)	Micro HUD	.89	28	1.42	3.36	10.09	3.0
XAX110	NEW	Integrated Communication Control	.92	20	1.13	1.73	5.20	3.0
XAX120	NEW	Integrated Navigation Control	.97	108	2.52	2.97	14.04	5.0
CAX130	(C5)	Signal Converter	.91	28	1.46	2.72	8.17	3.0
AAY110	(A7D)	Mission Computer	.90	31	1.20	3.38	10.16	3.0
AA2180	(A7D)	CRT (3)	.96	40	1.28	2.28	6.88	3.0
FA2180	(F111D)	Digital Scan Converter	.98	138	1.06	3.00	8.98	3.0

Table 2 R&M SUMMARY – 2 MAN FLIGHT DECK AVIONICS

MTTR - mean time to repair on the flight line (hours)

MMH - mean maintenance manhours to repair on the flight line (hours)

MMR - maintenance men required to effect a flight line repair which is calculated as $\frac{MMH}{MTTR}$

The reliability and maintainability results for the landing gear are presented in Table 3. Since the entire landing gear configuration is drawn from the C-141, the comparable subsystem column is omitted.

Code	Item	Availability	MFHBMA	R&R	MTTR	MMH	MMR
GLG110	Main Gear	.92	29	46	2.23	9.85	4.3
GLG120	Nose Gear	96	56	85	2.74	10.94	4.0
GLG130	Controls	99	100	94	2.73	7.47	2.7
GLG140	Brakes/Anti-Skid	75	9	60	3.08	15.38	5.0
GLG150	Steering System	96	74	.95	3.34	10.03	3.0
GLG160	Emergency Systems	99	819	13	.72	3.44	2.0
GLG170	Wheels & Tires	.93	22	1.75	1.77	3.51	2.0

Table 3 R&M SUMMARY - LANDING GEAR

Maintenance manpower requirements are determined for each AFSC in terms of maintenance manhours per thousand flying hours (MMH/KFH) directly from the R&M model. The average number of men required per squadron for each AFSC and skill level is determined from the following formula.

$$\text{No. Men} = \frac{(\text{MMH/KFH})(\text{FH/Sq-YR})(\text{YR/12 months})}{(\text{Efficiency factor})(\text{Work days/month})(\text{Shift hours/day})}$$

where:

MMH/KFH - as applicable in maintenance hours/1000 flying hours

FH/SQ-YR = flying hours/per squadron-year = 7488 flying hours/year

YR/12 months = .083 year/months

Efficiency factor = .6

Workdays/month 21.7 maintenance days/month

Shift hours/day = 8 maintenance hours/maintenance day

The variables FH/Sq-YR, efficiency factor, work days/month, and shift hours/day represent a scenario. The scenario used for this demonstration was L8 FH/aircraft-day, 16 aircraft/squadron, 5 flying days/week, .6 efficiency factor, 21.7 work days/month, and 8 shift hours/work day. The maintenance manpower requirements for this scenario are depicted in Table 4 for all avionics and landing gear baselines. The major factor not considered here is launch rate. (Note: the R&M model provides an average value prediction. It does not consider the dynamics of the situation as does LCOM, a Monte Carlo model.)

AFSC	Title	Avionics 2MFD	Avionics 3MFD	Landing Gear
32850	Avionics Communications	18	21	
32830		9	10	
32851	Avionics Navigation	11	15	
32831		9	12	
32854	Avionics Inertial &	4	2	
32834	Radar Navigation	4	2	
42350	Aircraft Electrical	0.5	0.5	3
42330	Systems	0.4	0.4	2
42354	Aircraft Pneudraulics			3
42334				1
43151	Aircraft Maintenance	17	19	4
43131				2
53150	Machinist	0.1	0.1	0.3
53153	Airframe Repair	1	1	
53133				
53154	Corrosion Control			0.5
53134				
53155	Non-Destructive			0.4
53135	Inspection			0.1
Total		74	83	16.3

Table 4 MAINTENANCE MANPOWER REQUIREMENTS

Operations Manpower Requirements

The operations manpower requirements for an aircraft are relatively straightforward and are basically expressed in crews per aircraft. This factor coupled with the aircraft phase-in and phase-out schedule is used to determine lifetime operationsl manpower requirements. Both training pipeline and operations for a proposed AMST are depicted in Table 5.

TRAINING REQUIREMENTS

Position	FY84	FY85	FY86	FY87	FY88	FY89/03
Pilot	6	20	158	180	172	60
Copilot	6	20	158	180	172	60
Navigator*	6	20	158	180	172	60
Loadmaster	6	20	158	180	172	60

*four man crew only

OPERATIONS REQUIREMENTS

Position	FY84	FY85	FY86	FY87	FY88	FY89/03
Pilot	6	26	184	364	536	526
Copilot	6	26	184	364	536	526
Navigator*	6	26	184	364	536	526
Loadmaster	6	26	184	364	536	526

*four man crew only

Table 5 OPERATIONS MANPOWER REQUIREMENTS

Scope and Magnitude of Training and Technical Manuals for Maintenance Personnel

Inherent in CHRT is the treatment of training and job guide documentation as an interactive pair which is either conventional (deductive) or task-oriented (directive) in nature (see paragraph 1.2). The CHRT output in terms of HR requirements is an estimate of training course length and technical manual page quantity. Page quantities are further categorized into flight line or shop and into troubleshooting and non-troubleshooting. The source data for these estimates in the conceptual phase were drawn from Air Force Career Development training course content and the comparable system equipment technical manuals.

Career development courses exist for most AFSC's. These course lengths and the course material presented reflect the conventional approach. Course content generally follows the outline shown in Table 6. The task-oriented training factors, shown in parentheses opposite the conventional course outline in table 6, are used to adjust conventional course length to ask oriented course length. These task-oriented training factors were developed by behavioral scientists and are based on a knowledge of the objectives of this type training and a review of the literature describing this training.

CONVENTIONAL COURSE OUTLINE		TASK-ORIENTED TRAINING FACTOR
A.	Basic principles	(0.20)
B.	General information, fundamentals, and administration	---
	1. General	(0.95)
	2. Technical publications, paperwork	(1.10)
	3. Maintenance procedures	(0.90)
C.	Applied Principles	---
	1. General	(0.75)
	2. Specific	(1.00)
	3. Test Equipment	(1.20)
D.	Equipment related features	(0.50)
	1. Subsystem/LRU	---
	2. LRU component	---
E.	Maintenance requirements and equipment performance	(0.50)
	1. Standards, checks, adjustments	---
	2. Troubleshooting procedures/support equipment	---

Table 6 CONVENTIONAL/TASK-ORIENTED TRAINING RELATIONSHIP

Course length for the task-oriented approach is estimated by multiplying the conventional course time required for the various topics by the factors shown in parentheses. For example, the task-oriented approach provides little theory because the deductive reasoning process is effectively replaced by direction. Therefore, the time allotted to "Basic Principles" is only 20 percent of that in a conventional course. On the other hand, the use of directive material and test equipment is more heavily emphasized in a task-oriented course than in a conventional course. Therefore, "Technical publications, paperwork," and "Test Equipment" are more heavily emphasized in task-oriented training. The resulting estimates for the Air Force career development courses required to support the AMST avionics and landing gear are shown in Table 7.

AFSC	Title	Course Length	
		Conventional	Task-Oriented
32850	Avionics Comm		
32830		28 wks	13 wks
32851	Avionics Nav		
32831		30 wks	13 wks
32854	Avionics Inertial &		
32834	Radar Nav	27 wks	15 wks
42350	Aircraft Electrical		
42330	Systems	19 wks	11 wks
42354	Aircraft Pneudraulics		
42334		11 wks	8 wks
43151	Aircraft Maintenance		
43131		11 wks	8 wks
53150	Machinist		
53153	Airframe Repair		
53133		13 wks	8 wks
53154	Corrosion Control		
53134			
53155	Non-Destructive	3 wks	2 wks
53135	Inspection	14 wks	10 wks

Table 7 COURSE LENGTH

Technical manual page and page type estimates are made with specially developed algorithms. A separate set of algorithms is required for conventional and task-oriented estimates. Within each set, a separate algorithm may be required for each of four task categories: non-troubleshooting flight line; non-troubleshooting shop; troubleshooting flight line; troubleshooting shop. These algorithms may also be unique to an equipment category. For example avionics and landing gear are technically dissimilar and require different algorithms. A flight instrument/control system and an avionics system are similar and would sue the same algorithms. The major variables in each of these algorithms are the number of subsystems, LRUs and SRUs in a system and the types of maintenance actions required to support each subsystem, LRU and SRU.

The page estimates developed during the conceptual phase demonstration are shown in Table 8. Estimates are in page quantity and were developed for both conventional and task-oriented technical manuals. For each type manual, page estimates were further broken down into non-troubleshooting (NTS) and troubleshooting (TS) for both flight line (FL) and shop (S). The algorithms and cost data which are presented in Volume II address the additional detail level of page type such as narrative, action page, schematic and pictorial. This detail, however, was not presented in the estimate because the algorithms and cost data were drawn from too limited a data base. This data base was extended during the validation phase demonstration and all algorithms and cost data were improved.

Baseline Configuration	Conventional Pages				Task-Oriented Pages			
	NTS-FL	TS-FL	NTS-S	TS-S	NTS-FL	TS-F	NTS-S	TS-S
Landing Gear	394	180	254	139	1700	305	1620	284
2 Man Avionics	168	194	1554	1717	960	316	4628	1597
3 Man Avionics	158	178	1433	1608	900	289	4240	1496

Table 8 JOB GUIDE CONTENT

Training for Operations Personnel

AMST operator course length was derived from a consideration of a comparable training course for the C-130 crews, equipment performance, avionics options, and a preliminary operator task list. The latter was derived from conceptual phase data and is provided in Volume II. It identifies those tasks unique to the AMST. The unique tasks are flight engineer type tasks, which must now be assumed by the pilot and copilot, and navigator tasks, which also will have to be assumed by the pilot and copilot if the two-man flight deck concept is implemented. The list was reviewed against the C-130 course schedule and a judgment made as to AMST course length for both the 2MFD and 3MFD options. The results are shown in Table 9.

Aircraft System	Course Length*			Number of Man Days per Course**		
	Initial	Mission	Total	Initial	Mission	Total
C-130 (5 man crew)	41	36	77	205	144	349
AMST 3MFD (4 man crew)	46	39	85	184	156	340
AMST 2MFD (3 man crew)	49	43	92	147	129	276

*Calendar days
**Crew size X course length

Table 9 OPERATOR COURSE LENGTH

SOC

SOCs were derived as appropriate for the cost categories listed in Table 10. Some cost equations used were original while others were modified and/or drawn from the Air Force Logistics Command (AFLC) Logistic Support Cost Model and from the DAIS LCC study. The annual cost of the aircrew (C_{AC}), for example, was calculated as follows:

$$C_{AC} = \underbrace{(CPA)(OA)}_{\text{no. of crews}} \sum_{p=1}^{P} \underbrace{(ABPR_p + YOSR_p + BAQ_p + ACI_p + BAS_p)}_{\text{cost of aircrewman}}$$

ABPR = annual base pay rate
YOSR = years of service pay adder
BAQ = basic allowance for quarters
ACI = aviation career incentive pay
BAS = basic allowance for subsistance
CPA = number of crews per aircraft
OA = number of operational aircraft in fleet
p = subscript identifying the p^{th} member of the aircrew
P = number of members in aircrew

The remaining SOC equations used are provided in Volume II.

Input data to these equations are categorized as either standard or unique. Standard data cover such areas as salary, training costs, and spares pipeline time. Standard data are drawn from officially maintained sources such as pay and allowance tables and AFR 173-10. Unique data cover the HR requirements as quantified within CHRT such as maintenance manpower requirements. Other unique factors such as equipment quantities and delivery schedule, operational applications, and crew makeup are drawn from system related sources such as the comparability analysis, operations plans, and system specifications. The AMST unique data used during this phase of the CHRT demonstration may be found in Volume II.

Annual SOC estimates developed from CHRT application with AMST conceptual data are listed in Table 10.

Cost Category	2MFD Avionics	3MFD Avionics	New Landing Gear	Modified Landing Gear
Support Equipment	3,333,000	3,333,000	TBD	TBD
Job Guides	80,500	61,000	40,400	24,200
Spares	4,122,000	4,852,000	495,000	396,000
Facilities				
Aircrew	18,296,500	24,614,000	N/A	N/A
Fuel	N/A	N/A	N/A	N/A
Equipment Maintenance	17,534,500	22,300,500	4,143,000	4,143,000
Training Maintenance	3,543,500	3,967,500	344,500	344,500
Training Aircrew	8,490,000	11,307,000	N/A	N/A
Depot Repair	9,164,000	9,156,000	2,299,500	2,299,500
Inventory Management	42,000	34,000	29,500	18,500
Software Support	750,000	N/A	N/A	N/A
Disposal	N/A	N/A	N/A	N/A
TOTAL	65,347,000	79,626,000	7,351,900	7,225,700

NA – not applicable

TBD – to be determined

Table 10 ANNUAL SYSTEM OWNERSHIP COSTS

All cost categories directly associated with avionics and landing gear have been covered in Table 10, except landing gear support equipment. Data, as well as a computational method, were lacking for the flight line and shop landing gear support equipment; therefore, these costs are noted as to be determined (TBD). The support equipment costs for avionics are for shop only. Cost categories that are not directly applicable to either avionics or landing gear are noted as N/A.

It should also be noted that although SOC consists of both support investment, a non-recurring cost; and O&S cost, a recurring cost; both have been treated on an annual basis. Additionally, some cost categories such as job guides and training should have both a non-recurring and recurring element. This lack of differentiation was a limitation of the method utilized for computing costs and was corrected in the validation (prototype) phase demonstration. Furthermore, the research and development and system acquisition costs must be identified before a complete cost picture can be presented to the decision makers. In this case, there is a significant difference in acquisition costs for the 2MFD and 3MFD avionics. This difference while not documented here will be discussed in the results of the validation phase.

HR and SOC Impact of Baseline(s) and Alternative(s)

The HR and SOC data developed through the CHRT process have now been presented for each of the four baselines. To be used effectively to invluence the selection of a specific baseline, the HR and SOC data must be presented in a format which facilitates comparison. In any case, HR and SOC data must be supplemented with appropriate performance, risk, acquisition cost, operations, and schedule impact data before a rational decision can be made. This portion of the report therefore does not address decision making, but rather the presentation to the decision maker of the data that are available through the CHRT process.

The HR and SOC impact of the 2MFD versus 3MFD avionics options is presented in various formats by Tables 11, 12 and 13. Each format is discussed in the following paragraphs.

The 2MFD and 3MFD avionics options share a significant amount of equipment as noted in Table 11. The major difference is that the 2MFD configuration includes integrated communication and navigation controls thus eliminating the need for discrete controls and incorporates a multiple CRT display capability. A mission computer coordinates communications, navigation, and display callup and provides additional computing functions which ease the workload on the reduced flight deck crew. Table 11 compares key reliability and maintainability related data. Specifically, the presentation depicts the impact on availability, MFHBMA, and on MMH/FH of the two options. One may conclude from this presentation that the 2MFD avionics offers improved availability and reliability (MFHBMA) with reduced maintenance requirements (MMH/FH).

	2MFD vs 3MFD Avionics			Availability	MFHBMA	Δ MMH/FH
2MFD AND 3MFD COMMON*	FAC110	(FB111)	HF Radio (2)	.52 vs .47	5 vs 4	0.08
	DAC210	(C130E)	VHF/FM Radio	.998 vs .994	400 vs 200	0.01
	GAC220	(C141)	VHF/AM Radio	.96 vs .92	52 vs 24	0.15
	CAC320	(C5)	UHF Radio (2)	.97 vs .91	37 vs 27	0.08
	DAC330	(C130)	UHF-DF			
	DAC410	(C130E)	Intercom			
	DAC420	(C130)	Public Address			
	DAC510	(C130)	IFF			
	BAC520	(B52G)	IFF Computer			
	BAC620	–	Secure Voice			
	CAC710	–	Crash Position			
	FAN120	(FB111)	TACAN			
	GAN130	(C141)	VOR/ILS (2)		38 vs 33	0.03
	GAN140	(C141)	LF-DF	.95 vs .91	62 vs 32	0.15
	AAN210	(A7D)	Radar Altimeter (2)			
	CAN230	(C5)	Omega			
	EAN240	(C135)	Radar	.62 vs .52	6 vs 4	1.09
	DAN280	(C130E)	SKE	.78 vs .75	11 vs 9	0.2
	TAN320	(T43)	INS	.90 vs .89	22 vs 18	0.07
	AAN380	(A7D)	Micro HUD (2 vs 1)	.89 vs .94	28 vs 56	-0.18
2MFD ONLY	XAX110	NEW	Integrated Communication Control	.92	20	-0.28
	XAX120	NEW	Integrated Navigation Control	.97	100	-0.14
	CAX130	(C5)	Signal Converter	.91	28	-0.20
	AAY110	(A7D)	Mission Computer	.90	31	-0.33
	AAZ190	(A7D)	CRT (3)	.96	40	-0.17
	FAC180	(F111D)	Digital Scan Converter	.98	130	-0.06

*Discrete communication and navigation controls are eliminated in the 2MFD option.

Table 11 R&M IMPACT ON 2MFD VS 3MFD AVIONICS

In a similar manner, Table 12 presents the maintenance manpower impact. Overall, nine fewer maintenance men are required to support the 2MFD option.

AFSC	Title	Avionics 2MFD	Avionics 3MFD	Δ
32850	Avionics Comm	18	21	3
32830		9	10	1
32851	Avionics Nav	11	15	4
32831		9	12	3
32854	Avionics Inertial	4	2	-2
32834	Radar Nav	4	2	-2
42350	Aircraft Electrical	R	R	
42330	Systems	R	R	
42354	Aircraft Pneudraulics			
42334				
43151	Aircraft Maintenance	17	19	2
43131				
53150	Machinist	R	R	
53153	Airframe Repair	1	1	
53133				
53154	Corrosion Control			
53134				
53155	Non Destructive			
53135	Inspection			
	TOTAL	73	82	9

R = required manpower 0.5

Table 12 MAINTENANCE MANPOWER IMPACT (MEN PER SQUADRON)

2MFD vs 3MFD AVIONICS

The SOC impact is presented in Figure 13 for the 2MFD versus 3MFD. The advantage is to the 2MFD avionics suite mainly because of the reduced crew and maintenance costs. The advantage may be quantified in terms of SOC as $14,270,000 per year.

Cost Category	2MFD Avionics	3MFD Avionics	Δ
Support Equipment	3,333,000	3,333,000	
Job Guides	80,500	61,000	-19,500
Spares	4,122,000	4,852,000	+731,500
Facilities			
Aircrew	18,296,500	26,614,000	+8,317,500
Fuel	N/A	N/A	
Equipment Maintenance	17,534,500	22,300,500	+4,766,000
Training Maintenance	3,543,500	3,967,500	+424,000
Training Aircrew	8,490,000	11,307,000	+2,817,000
Depot Repair	9,164,000	9,156,000	-8,000
Inventory Management	42,000	34,000	-8,000
Software Support	750,000	N/A	
Disposal	N/A	N/A	
TOTAL	65,347,000	79,626,000	+14,270,000

Table 13 SYSTEM OWNERSHIP COST IMPACT

2MFD vs 3MFD AVIONICS

No significant technical differences were identifiable between a new and a modified landing gear due to inadequate design definition. A commonality factor for a modified gear of 80 percent common parts was assumed, however. The impact of this assumption may be discerned directly from a previous presentation Table 10, Annual System Ownership Costs. The impact is quantifiable as a potential advantage of $125,000/year for a modified gear. Although an advantage to using a modified gear might be intuitively assumed, acquisition costs and more detailed design data are needed for a decision. The point to note here is that the CHRT process will quantify a factor such as commonality.

High Drivers

High drivers are defined within CHRT as areas which require excessive HR or SOC. Excessive must be defined by acquisition management so that HR and SOC data may then be screened by some established criteria. Table 14 represents a technique that could be employed for identifying reliability and maintainability related high drivers in the landing gear area.

Screening Values		.85	10	1.00	2.00		4.0
		ASSESSMENT FACTORS					
Subsystem		Availability	MFHBMA	R&R	MTTR	MMH	MMR
GLG110	Main Gear				2.23	9.65	4.3
GLG120	Nose Gear				2.74		
GLG130	Controls				2.73		
GLG140	Brakes/Anti Skid	.75	9	3.08	3.08	15.38	6.0
GLG150	Steering System				3.34		
GLG160	Emergency Systems						
GLG170	Wheels & Tires			1.75			

Table 14 R&M HIGH DRIVERS LANDING GEAR

Screening values and assessment factors (e.g., the screening value of 8.5 for the assessment factor of availability shown in Table 14 are established by the user or acquisition agency. Only those assessment factors exceeding the screening values are displayed for review. A separate presentation is provided for each equipment configuration.

A review of Table 14 indicates that based on comparability data, the brakes/anti-skid subsystem of the landing gear and the general area of mean time to repair for the total landing gear system are likely to be high drivers for a C-141 type landing gear since they exceed the screening values established. If a modified C-141 gear was chosen, immediate action should be taken to specifically determine the reliability and maintainability problems associated with the brakes/anti-skid subsystem. Since both the new or modified gear represent the same basic technology, one might investigate the reasons behind the high MTTR or even question the screening value. A possible conclusion is that considerable time is required in jacking the aircraft. The problem, therefore, may not be with the aircraft itself, but with support equipment. In either case, alternatives might have to be considered and their impact in terms of HR and SOC determined through a reiteration of CHRT.

"High drivers" were also identified for both avionics options. These are depicted in Tables 15 and 16. The avionics data represent actual field experience with the same off-the-shelf avionics equipment being considered for the AMST. Since so many assessment factors exceed the screening value, further investigation is mandatory. The comparability association should first be verified and data corrected as necessary. If excessive assessment factors still exist, the cause for the unacceptable performance should then be identified. In this case, the screening values assigned were drawn from the AMST ROC. Possible causes include poor technical design, difficult access on the comparable aircraft system, inadequate training or technical manuals or incompatible support procedures. Once a potential corrective action is identified, it can be reevaluated through the CHRT process. The user should also consider reducing requirements (screening values) where possible.

Screening Value			85	10	1.00	2.00		3.0
Subsystem			Availability	MFHBMA	R&R	MTTR	MMH	MMR
FAC110	(FB111)	HF Radio (2)	47	4	2.82	4.56	13.86	
DAC210	(C130E)	VHF/FM Radio						
GAC220	(C141)	VHF/AM Radio				2.12		
CAC320	(C5)	UHF Radio (2)			1.04	2.87		
DAC330	(C130)	UHF DF					5.16	3.9
DAC410	(C130E)	Intercom	86	4		2.04	6.12	
DAC420	(C130)	Public Address				3.88	12.86	3.4
DAC510	(C130)	IFF			1.01	3.08		
BAC520	(B52G)	IFF Computer				3.90		
BAC620	--	Secure Voice			1.40	3.70		
CAC710		Crash Position				2.38	9.98	4.0
FAN120	(FB111)	TACAN			1.78	2.16		
GAN130	(C141)	VOR/ILS (2)						
GAN140	(C141)	LF DF			1.51	3.19		
AAN210	(A7D)	Radar Altimeter (2)			1.23	2.36		
CAN230	(C5)	Omega			1.38	3.62		
EAN240	(C135)	Radar	52	4	1.73	3.42	12.81	3.8
DAN280	(C130E)	SKE	75	9	1.26	2.90	9.90	3.3
TAN330	(T43)	INS				2.19		
AAN380	(A7D)	Micro HUD			1.42	3.36		

Table 15 R&M HIGH DRIVERS AVIONICS 3 MAN FLIGHT DECK

Screening Values			85	10	1.00	2.00		3.0
Subsystem			Availability	MFHBMA	R&R	MTTR	MMH	MMR
FAC110	(FB111)	HF Radio (2)	.52	5	2.62	4.56	13.86	
DAC210	(C130E)	VHF/FM Radio						
GAC220	(C141)	VHF/AM Radio				2.12	6.36	
CAC320	(C5)	UHF Radio (2)			1.04	2.67	8.01	
DAC330	(C130)	UHF-DF					5.16	3.9
DAC410	(C130E)	Intercom	.66	4		2.04	6.12	
DAC420	(C130)	Public Address				3.09	12.86	3.4
DAC510	(C130)	IFF			1.01	3.09		
BAC520	(B52G)	IFF Computer				3.80		
BAC620	–	Secure Voice			1.40	3.70		
CAC710	–	Crash Position				2.30	9.50	4.0
FAN120	(FB111)	TACAN			1.78	2.16		
GAN130	(C141)	VOR/ILS (2)						
GAN140	(C141)	LF-DF			1.51	3.19		
AAN210	(A7D)	Radar Altimeter (2)			1.23	2.36		
CAN230	(C5)	Omega			1.38	3.62		
EAN240	(C136)	Radar	.62	6	1.73	3.42	12.81	3.8
DAN250	(C130E)	SKE	78		1.26	2.90	9.98	3.3
TAN330	(T43)	INS				2.19		
AAN360	(A7D)	Micro HUD			1.42	3.36		
XAX110	NEW	Integrated Communications Control			1.13			
XAX120	NEW	Integrated Navigation Control			2.52	2.97	14.84	5.0
CAX130	(C5)	Signal Converter			1.46	2.72		
AAY110	(A7D)	Mission Computer			1.20	3.38		
AAZ150	(A7D)	CRT (3)			1.28	2.29		
FAZ180	(F111D)	Digital Scan Converter			1.86	3.00		

Table 15 R&M HIGH DRIVERS AVIONICS 2 MAN FLIGHT DECK

Training and Technical Manual Products

The planned product for the conceptual phase was an integrated personnel, training, and technical manual concept. In addition to estimating the length of training and number of technical manual pages, as was accomplished, another goal was to identify required levels of detail and depth of coverage in both technical manuals and training for the integrated personnel, training, and technical manual approach desired. This identification was to be accomplished through a task intensity profile developed using the R&M model output. A technique to accomplish this was developed and implemented.

A review of the technique and results, however, indicated an incompatability in the comparability data input to the R&M model. These data had not been normalized to represent the desired integrated personnel, training, and technical manual concept. Specifically, the input data drawn from technically comparable systems was not logistically comparable. The systems were maintained and supported by various skill levels, types of training and both deductive and directive technical manuals. These data should have been normalized to the integrated approach selected for the equipment under consideration. This shortcoming was noted and has since been corrected. The new analysis technique is discussed in Section III of this report.

The actual training and technical manual product developed in this phase of the demonstration was a description of the prescribed AMST personnel, training, and technical manual concept. This concept addresses basically 5-skill-level manning, conventional training, and task-oriented technical manuals. Because of the combined conventional and task-oriented nature of the three elements, this concept cannot be considered an integrated approach.

2.4 CONCLUSIONS - CONCEPTUAL PHASE

Overall, this phase of the CHRT demonstration has shown that extensive HR and SOC data can be developed and quantified for a weapon system acquisition program through a rational, repeatable and traceable process as early as the conceptual phase. More specifically, the conclusions are:

A. Application of the CHRT process and the CDB is feasible in the conceptual phase.

   1. The R&M model is adequate for estimating maintenance manpower requirements and reliability and maintainability data.

   2. The techniques used for estimating operations manpower and operations and maintenance course length are at least adequate for conceptual phase estimates.

   3. The CHRT process appears well suited to address the question of affordability of alternatives at their conceptual development stage.

The conceptual phase CHRT products have been identified and representative samples have been provided and evaluated for utility.

1. The CHRT products in the conceptual phase are HR and SOC estimates for system and subsystem alternatives. The HR estimates include reliability, maintainability, maintenance manpower, training, and technical manuals for maintenance, operations manpower, and training requirements for operations.

2. The CHRT process considers and these estimates uniquely reflect the interrelationship among the design, logistic, and operational elements of the weapon system. This occurs because these elements are characteristics of the maintenance action networks from which CHRT estimates are derived.

3. The information and visibility provided by these estimates can be used to more effectively manage an acquisition program, support decision making, identify potential problem areas, and detail the information necessary for DSARC reviews. This is possible because the HR and SOC estimate presents a concise impact statement related to a specific design, logistics, and/or operations approach. Furthermore, this statement may be modified through the CHRT process to reflect the impact of an alternate approach in one or more of the three areas mentioned.

4. The estimates do facilitate comparison of alternatives and allow identification of "high drivers."

5. "High driver" and comparison formats should continue to be evaluated for improved presentation of HR and SOC data.

The CDB, as conceived, supports the CHRT process with minor exceptions.

1. The content and format of the CDB will remain subject to change until the completion of this demonstration. In this

way, it may be uniquely and efficiently tailored to support the total CHRT process.

2. The analytic tools to support derivation of the CHRT products must be part of this CDB because they are as important to the process as the input information.

3. Estimates related to several technologies can be developed from a single data source.

D. Inadequacies and/or inconsistencies in the CHRT process and the CDB have been identified. All have either been corrected or earmarked for future consideration.

1. Each equipment baseline and alternative must include a specific support concept. The latter has direct effect on HR requirements and system ownership cost.

2. The comparability analysis required for the development of maintenance action networks must address the support design, particularly personnel, training, and technical manuals, as well as the system design so that HR and SOC estimates may reflect the characteristics of the total system.

3. In addition to career development training, both technical training and on-the-job training should also be addressed in order to reflect the complete training picture.

4. Although adequate for the conceptual phase, job guide content algorithms and available cost data must be improved in accuracy for validation (prototype) phase estimates.

5. SOC equations must be improved for a finer breakdown of categories and separation of non-recurring and recurring costs. Phase-in and phase-out capability should be developed so multiple-year costs may be shown. These capabilities when developed may be applied in the conceptual phase.

III. DEMONSTRATION IN THE VALIDATION PHASE

3.1 OVERVIEW

The demonstration of CHRT as applied in the validation phase was conducted during the 6 month period 16 January 1978 to 15 July 1978. AMST prototype phase data were the prime source of information. The kind and quality of data available for use with CHRT in the avionics and landing gear area were typical of data available for use in the validation phase. Three of the four configurations identified in the conceptual phase were carried forward for continued analysis. These were the 2MFD and 3MFD avionics and the modified C-141 landing gear. An additional avionics alternative, integrated digital avionics for AMST (IDAMST) was also identified for consideration. During this phase, a technique was implemented to reflect in the maintenance action networks an integrated personnel, training, and technical manual approach to either a conventional or task-oriented support program. Therefore both conventional and task oriented support programs were also considered as options.

The results of this phase indicate that the CHRT process and CDB have continued and extended application during the validation phase. HR and SOC estimates were again developed for all baselines and alternatives identified. These data were now more accurate reflections of the logistic requirements for two reasons. One, improved technical manual content algorithms, more accurate technical manual cost data and updated SOC equations were developed for and employed in this phase. Two, the integrated approach to personnel, training, and technical manuals reflected in the input data produced a coordinated set of personnel, training, and technical manual requirements. Additionally, the CHRT process was used for the first time to evaluate a major piece of equipment within a subsystem, thus taking advantage of the additional detail available in the validation phase.

The HR data derived were also used as a direct input to a proposed "Integrated Personnel, Training, and Job Guide" Section of the AMST Integrated Logistic Support Plan (ILSP). This document presents a realistic level of detail not previously available in an ILSP developed from validation phase data. A newly developed CHRT product of this phase was also included in this ILSP section. This product is called a task identification matrix and was developed for each subsystem. The matrix describes within a given subsystem and for a specific personnel training and technical manual approach, the degree of emphasis required in both the training and technical manual areas for various items of hardware.

During this part of the demonstration, the CDB was updated for accuracy and expanded in detail and content. The additional detail reflected design maturity and a more detailed equipment description. The content was expanded to include an improved SOC model, the task intensity matrix, and additional support data.

3.2 AMST PROTOTYPE PHASE AND SUPPLEMENTARY DATA SOURCES

The AMST prototype phase occurred during 1976 and 1977. Two contractors, Boeing and McDonnell Douglas, participated. Each proposed a singular and unique design. Both proposals were available as source data for CHRT and were thoroughly reviewed. The applicable ROC and Employment Concept Document were used as the prime sources of supplementary data.

Two prototypes of each design were built. They were evaluated by the Air Force, primarily, for technical and operational performance. Although more hardware oriented than a typical validation phase, the AMST prototype phase pursued basic validation phase goals. These were validation of the technical approach and reduction of technical risk. The AMST prototype phase achieved these goals through extensive hardware development.

The quality of avionics and landing gear data, however, was typical of validation phase. Very little actual hardware derived data were developed for these systems. Avionics were to be predominantly government furnished equipment (GFE) and were not a major contractor concern. The landing gear was being evaluated primarily for performance and very little descriptive or maintenance data were gathered.

The major sources of avionics information during this phase were several studies accomplished by the Aeronautical Systems Division, the Air Force Avionics Laboratory, and the Air Force Flight Dynamics Laboratory. All studies are excellent examples of the depth of investigation possible in the validation phase.

Design and maintenance data for the individual landing gear systems proposed by each contractor were documented in a prototype phase comparability analysis and associated maintenance action networks. These data, however, were part of the minimum engineering development (MED) phase proposals. As a result, these data were considered source selection sensitive and were not made available for this study. As an alternative, therefore, the conceptual phase generic AMST comparability analysis and maintenance action networks were updated using the prototype phase avionics studies and 1976 time frame, C-141 landing gear maintenance data drawn from USAF Logistic Support Cost File Maintenance Register-66-1/IROS, K051, PN8L. Both these sources provided the level of detail data appropriate to the validation phase.

3.3 CHRT RESULT - VALIDATION (PROTOTYPE) PHASE

The results of the CHRT demonstration are presented and discussed under the following topics:

- Baseline(s) and alternative(s)
- Reliability, maintainability, and maintenance manpower requirements
- Operations manpower requirements
- Scope and magnitude of training and technical manuals for maintenance personnel
- Scope of training for operations personnel
- SOC
- HR and SOC impact of baseline(s) and alternative(s)
- High drivers
- Training and technical manual products

Samples of data will continue to be included in the discussion or in Volume II as appropriate. The data developed were based on the ROC current at that time which assumed 277 aircraft: 256 UE; and 21 NOA. Sixteen operational squadron were split between two overseas locations. The training squadron was located at one of the CONUS bases. Aircrew/aircraft ratio was 2:1 per UE and per NOA used for training. Utilization rate was 1.8 hours/day during a 5 day week.

Baseline(s) and Alternative(s)

The first step accomplished in the prototype phase was to update the DODTs and alternative listings. The AMST system, general avionics, and general landing gear DODTs, as updated to the prototype phase, are included in Volume II. Additionally, a DODT was developed for alternative logistic options. This is shown in Figure 8 and depicts the possible alternatives in support equipment, maintenance/personnel/training/job guide approach, and spares philosophy. The logistics tree's blocks are annotated with a C or T to reflect the appropriate paths for either a conventional(C) or a task-oriented(T) personnel/training/job guide approach. The maintenance, operations, and support alternatives not directly discernible from the DODTs but identified in the prototype phase documentation were documented in the alternative listing as follows:

- 2MFD versus 3MFD crew
- Limited adverse weather aerial delivery system (AWADS)
- Aircraft radius of action
- Payload
- STOL field length
- Runway quality

The information required to develop and/or update the DODTs and the alternative listing was obtained from the Boeing YC-14 and McDonnell Douglas YC-15 prototype proposals, the Air Force avionics studies, and C-141 technical data. A review of the DODTs and the alternative listing resulted in the identification of three baselines and five alternatives. The baseline configurations were:

- 2MFD avionics - conventional ISD/JGD
- Modified C-141 landing gear - conventional ISD/JGD
- Installed station-keeping equipment

The alternatives identified were:

- 2MFD avionics - task-oriented ISD/JGD
- 3MFD avionics - conventional ISD/JGD
- IDAMST - conventional ISD/JGD
- Modified C-141 landing gear - task-oriented ISD/JGD
- Insertable station-keeping equipment

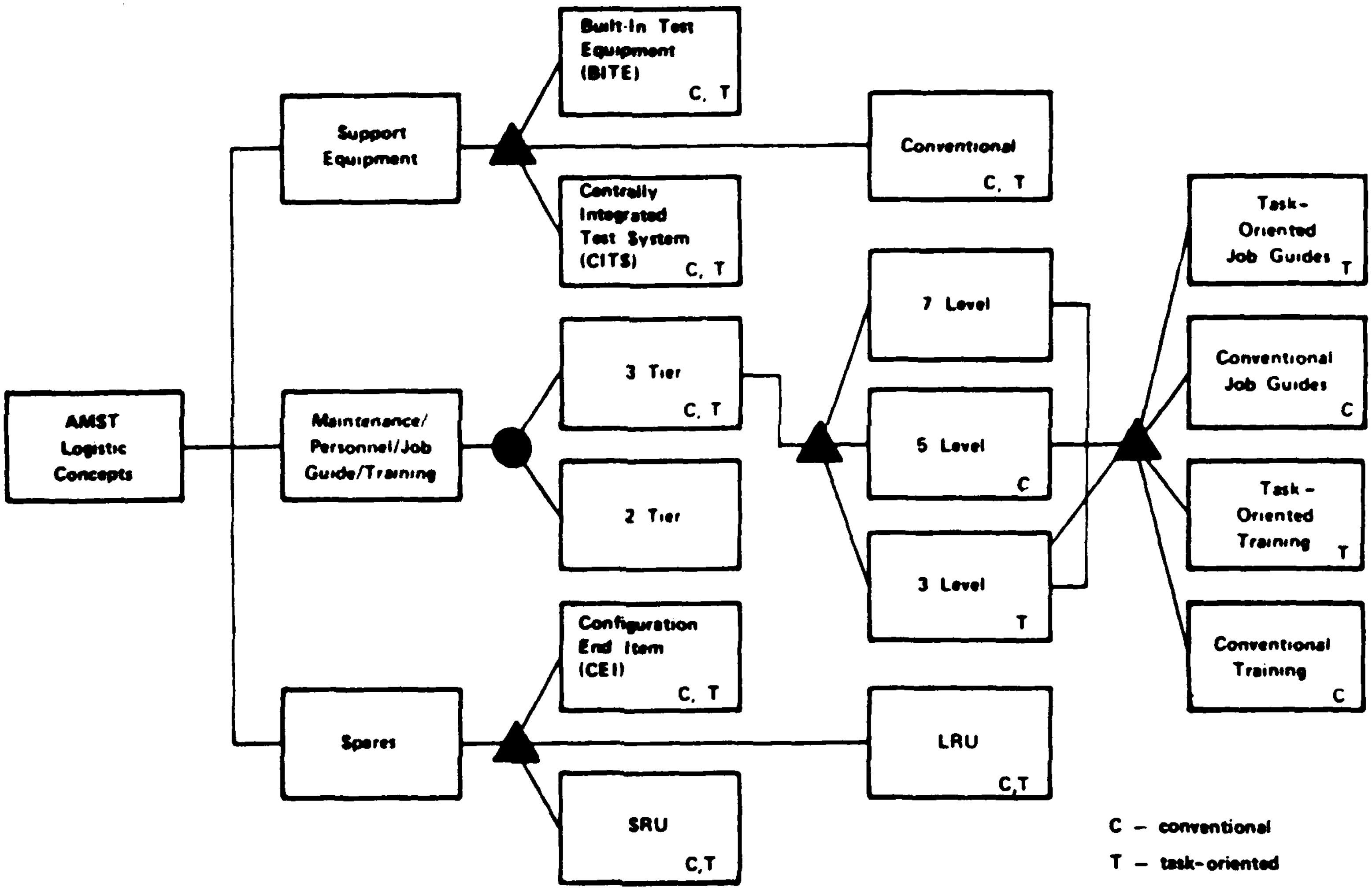


Figure 8 DESIGN OPTION DECISION TREE FOR LOGISTICS

The two and three man avionics suites are basically the same configurations addressed previously but at a more detailed level. IDAMST is a digital system for two man operation. The landing gear is considered a modified C-141 type. Although the YC-14 and YC-15 incorporate different designs, both represent similar technology and utilize portions of existing designs. The more detailed design differences are shown in Figure 9. Portions of the main and nose gear design option decision trees are reproduced in this figure and annotated C-14 or C-15 at the bench-point of the design difference. The conventional and task-oriented ISD/JGD approaches can also be realistically considered as alternatives since each approach may be reflected in the maintenance action network input data. Finally, a subsystem level alternative, insertable SKE was selected. SKE makes up a portion of the adverse weather aerial delivery system (AWADS). Insertable SKE addresses the alternative listing item of limited AWADS. The insertable approach is feasible since AWADS is required only on selected flights. Insertable SKE, therefore, theoretically represents a way to reduce life cycle costs since a reduced number of units would be required and less maintenance would be anticipated.

Reliability (R), Maintainability (M), and Maintenance Manpower Requirements

The AMST comparability analysis and maintenance action networks for the subsystems addressed in the conceptual phase were updated to reflect the more detailed design data and improved information available in the prototype phase. These subsystems were the 2MFD and 3MFD avionics and the modified C-141 landing gear. Additionally, a new configuration and a network were prepared for the IDAMST option. All networks were prepared to reflect a rather traditional or conventional approach to personnel, training, and job guides. Specifically, this was 5-skill-level manning supported by 3-skill-level helpers, conventional training, and conventional technical orders. An additional set of maintenance action networks reflecting a task-oriented option was also developed for the 2MFD avionics and the modified C-141 landing gear.

Tables 17 and 18 present the R&M summaries for the 3MFD avionics and the IDAMST avionics, respectively. Both configurations reflect the conventional approach to personnel, training, and technical manuals. The 3MFD configuration represents a simple avionics suite composed of discrete off-the-shelf components with discrete displays and controls. The IDAMST on the other hand represents a very sophisticated and totally integrated conceptual

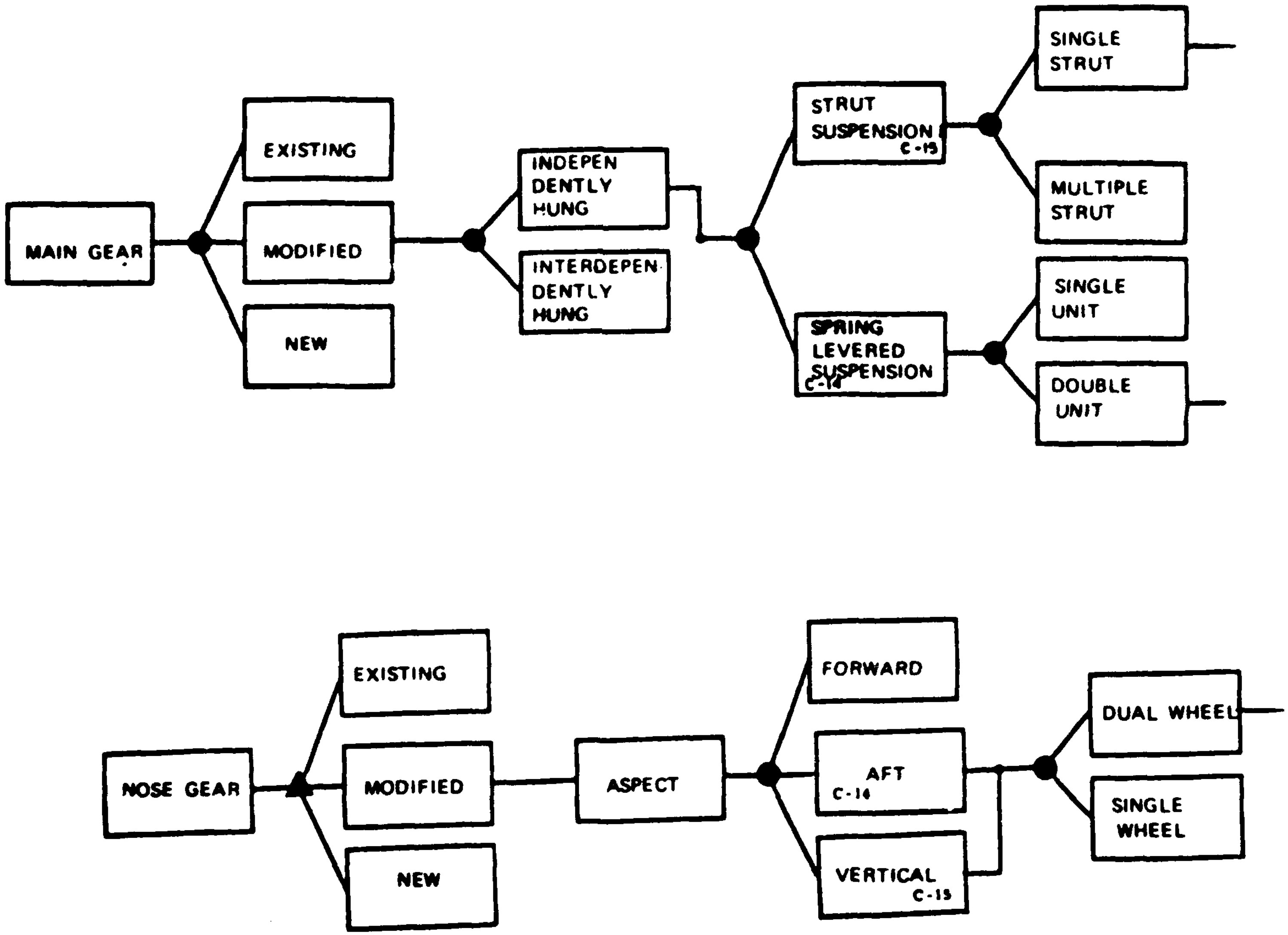


Figure 9 LANDING GEAR OPTIONS

Item	Availability	MFHBMA	FL R&R	FL MTTR	FL MMH/FH	Shop MMH/FH
HF Radio (2)	.8086	7.1	2.82	4.56	1.921	.881
VHF/FM Radio	.9876	293.9	0.94	1.27	0.013	.008
VHF/AM Radio	.9528	42.8	0.74	2.12	0.149	.138
UHF Radio (2)	.9368	38.0	1.04	2.67	0.206	.082
UHF-DF	.9983	800.0	0.17	1.33	0.006	.001
Intercom	.7463	6.0	0.56	2.04	1.020	.114
Public Address	.9881	306.0	0.86	3.70	0.041	.002
IFF	.9846	200.0	1.01	3.1	0.047	.006
IFF Computer	.8908	35.0	0.70	3.90	0.334	.080
Secure Voice	.9966	840.0	1.40	3.70	0.013	.003
Crash Position	.9615	47.0	0.91	2.38	0.204	.033
TACAN	.9870	164.0	1.78	2.17	0.040	.046
VOR/ILS (2)	.9613	46.4	0.70	1.87	0.121	.083
LF-DF	.9146	34.1	1.51	3.19	0.280	.106
Radar Altimeter (2)	.9876	187.0	1.23	2.36	0.038	.006
Omega	.8889	29.0	1.38	3.63	0.376	.383
Radar	.5632	4.4	1.73	3.56	2.913	1.006
SKE	.8750	20.9	1.26	2.98	0.478	.106
INS	.8014	18.0	0.86	2.19	0.366	.106
Micro HUD	.8828	28.0	1.42	3.38	0.380	.254

Table 17 R&M SUMMARY – 3MFD AVIONICS

Conventional Manning, Training, and Tech Manuals

Item	Availability	MFHBMA	FL R&R	FL MTTR	FL MMH/FH	Shop MMH/FH
HF Radio (2)	.8225	7.5	2.82	4.56	1.819	.866
VHF/FM Radio	.9868	400.0	0.94	1.27	0.010	.006
VHF/AM Radio	.9880	52.0	0.74	2.12	0.122	.128
UHF Radio (2)	9382	40.5	1.04	2.67	0.187	.081
UHF-DF	9983	800.0	0.17	1.33	0.006	.001
Intercom	.7463	6.0	0.56	2.04	1.020	.113
Public Address	9881	306.7	0.86	3.70	0.041	.002
IFF	9846	200.0	1.01	3.14	0.047	.006
IFF Computer	.8908	35.0	0.70	3.90	0.334	0.80
Secure Voice	9864	840.0	1.40	3.70	0.013	.003
Crash Position	9515	47.0	0.91	2.38	0.204	.084
TACAN	9870	164.0	1.78	2.17	0.040	.046
VOR/ILS (2)	9880	58.5	0.70	1.87	0.086	.064
LF-DF	9738	121.3	1.56	3.26	0.081	.026
Radar Altimeter (2)	.9876	187.0	1.23	2.36	0.038	.006
Omega	.8889	29.0	1.38	3.36	0.376	.363
Radar	.6280	6.0	1.73	3.56	2.136	.963
SKE	.8881	26.3	1.26	2.99	0.379	.058
INS	.9084	22.0	0.88	2.19	0.298	.136
Electronic Display Group	9988	1310.4	1.06	1.87	0.003	.003
Special Purpose Displays	.9801	41.2	1.14	1.76	0.081	.130
Display Controls	9804	86.7	1.16	1.71	0.042	.083
Mass Memory Unit	9791	126.9	1.90	2.72	0.046	.027
Multifunction Controls	.9978	826.3	1.01	1.82	0.006	.004
Dedicated Controls	9930	1082.4	1.30	2.18	0.004	.002
Processor	9648	38.8	0.86	1.84	0.113	.076
Remote Terminal System	.9781	106.7	1.07	2.38	0.048	.067

Table 18 R&M SUMMARY – IDAMST

Conventional Manning, Training, and Tech Manuals system. Although the basic sensors found in the 3MFD are retained in IDAMST, the discrete controls and displays are eliminated. The elimination of these discrete controls and displays accounts for increases in both availability and MFHBMA of the individual items in the IDAMST configuration. In the IDAMST, a highly reliable processor, core, display, and control group provide integration and replace the discrete displays and controls of the 3MFD avionics. For example, the availability of the VHF/AM radio in the IDAMST increases to .9690 from .9528 in the 3MFD avionics. This is because the discrete mechanical control has been eliminated and replaced by the electronic control group which has a very high reliability.

Before presenting the additional results, it is appropriate to list the very conservative actions taken to reflect the 3-skill-level, task-oriented ISD/JGD approach in updating maintenance action networks. The rationale for each action is provided in parentheses following the description of the action. The statement of the rationale is substantiated by a thorough review of the literature which addresses the implications of task-oriented training as supported by proceduralized aids. The actions and rationales are as follows. The percentages used are representative of conclusions found in the literature.

(1) Reduce the times for flight line cannot-duplicate, troubleshoot, and maintain on aircraft by 10 percent each. (Proceduralized aids reduce maintenance times.)
(2) Reduce flight line probability of cannot-duplicate by 50 percent and reduce the number of cannot-duplicate actions accordingly. (Proceduralized aids will increase possibility of first time diagnosis.)
(3) Increase MFHBMA, as appropriate, based on action (2) above.
(4) Reduce shop probability of cannot-duplicate by 50 percent and reduce the number of flight line remove and replace actions accordingly. (Proceduralized aids reduce false removals.)
(5) Increase the number of flight line cannot-duplicate actions by the same number as action (4) to reflect early cannot-duplicate determination. (Proceduralized aids reduce false removals.)

(6) Retain personnel quantity and AFSC skills, but modify skill levels as follows:
   (a) Assure that one AFSC 413X1 position is always a 5-skill-level to provide supervision.
   (b) Assure that all shop personnel called to flight line are 5-skill-level (no reduction in shop skills is assumed for this study).
   (c) Set all flight line specialists performing cannot-duplicate, troubleshooting, and remove and replace tasks at the 3-skill-level (proceduralized aids allow jobs to be performed by lesser skills).
   (d) For maintain on aircraft actions and each AFSC involved, set one specialist at the 5-skill-level and all others of the same AFSC at the 3-skill-level. (Maintain on aircraft is assumed to be a more difficult and complex action. Therefore, skills cannot be reduced.)

Tables 19 and 20 present the R&M summaries for the conventional and task-oriented options with the 2MFD avionics. Some integration of controls and displays is also provided in the 2MFD avionics but not to the same degree as IDAMST. The integration here is represented by the integrated communications control, the integrated navigation control, the integrated navigation signal converter, the mission computer, the three CRTs, and a digital scan converter. Processing and core, however, are held to a minimum.

The primary goal in the 2MFD avionics design is to reduce in-flight workload for compatibility with both the expected mission and a limited flight deck crew. The object of the comparison of Tables 19 and 20 is to consider the impact of a logistic alternative, the conventional versus task-oriented approach. A comparison of Table 19 with Table 17 or 18, on the other hand, facilitates the evaluation of a design alternative.

In comparing the task-oriented approach to the conventional approach for the 2MFD avionics and also for the landing gear (Tables 21 and 22), the reader should note that the assumed advantages of the task-oriented approach have been appropriately quantified. Availability increases, MFHBMA increases, MTTR decreases, and MMH/FH decreases. Other logistic alternatives could be quantified in a similar manner given the initial assumed

Item	Availability	MFHBMA	FL R&R	FL MTTR	FL MMH/FH	Shop MMH/FH
HF Radio (2)	.8225	7.5	2.82	4.56	1.819	.082
VHF/FM Radio	.9968	400.0	0.94	1.27	0.010	.006
VHF/AM Radio	.9808	52.0	0.74	2.12	0.122	.128
UHF Radio (2)	.9382	40.5	1.04	2.67	0.197	.081
UHF-DF	.9983	800.0	0.17	1.33	0.006	.001
Intercom	.7483	6.0	0.66	2.04	1.020	.113
Public Address	.9881	306.7	0.86	3.70	0.041	.002
IFF	.9846	200.0	1.01	3.14	0.047	.006
IFF Computer	.8908	36.0	0.70	3.80	0.334	.080
Secure Voice	.9956	840.0	1.40	3.70	0.013	.003
Crash Position	.9615	47.0	0.91	2.38	0.204	.064
TACAN	.9870	164.0	1.78	2.17	0.040	.046
VOR/ILS (2)	.9890	58.5	0.70	1.87	0.086	.054
LF-DF	.9738	121.3	1.56	3.26	0.081	.036
Radar Altimeter (2)	.9876	187.0	1.23	2.36	0.038	.006
Omega	.8889	29.0	1.36	3.63	0.376	.363
Radar	.6280	6.0	1.73	3.56	2.136	.963
SKE	.8861	26.3	1.26	2.98	0.379	.068
INS	.9094	22.0	0.86	2.19	0.288	.128
Micro HUD (2)	.8828	28.0	1.42	3.36	0.380	.284
Integrated Communications Control	.9802	58.7	0.96	2.47	0.124	.041
Integrated Navigation Control	.8886	28.1	2.14	3.52	0.827	.126
Signal Converter	.9114	28.0	1.46	2.72	0.282	.080
Mission Computer	.9015	31.0	1.20	3.38	0.328	.147
CRT (3)	.9457	40.0	1.28	2.30	0.172	.033
Digital Scan Converter	.9789	139.0	1.86	3.00	0.086	.042

Table 19 R&M SUMMARY – AVIONICS, 2MFD

Conventional Manning, Training, and Tech Manuals

Item	Availability	MFHBMA	FL R&R	FL MTTR	FL MMH/FH	Shop MMH/FH
HF Radio (2)	.8576	8.3	2.986	4.32	1.562	.839
VHF/FM Radio	.9980	400.0	0.94	1.24	0.009	.008
VHF/AM Radio	.9861	61.9	0.88	2.17	0.106	.126
UHF Radio (2)	.9436	42.6	1.04	2.56	0.180	.080
UHF-DF	.9984	800.0	0.17	1.25	0.006	.001
Intercom	.7671	6.5	0.58	1.97	0.911	.113
Public Address	.9898	340.8	0.88	3.51	0.036	.002
IFF	.9876	248.4	1.18	3.12	0.038	.006
IFF Computer	.9167	38.5	0.88	3.98	0.273	.067
Secure Voice	.9958	840.0	1.40	3.57	0.013	.003
Crash Position	.9682	56.6	1.02	2.42	0.174	.063
TACAN	.9873	164.0	1.79	2.11	0.039	.048
VOR/ILS (2)	.9752	80.7	0.96	2.06	0.076	.064
LF-DF	.9784	130.4	1.86	3.16	0.072	.026
Radar Altimeter (2)	.9883	204.4	1.20	2.21	0.032	.004
Omega	.9060	34.1	1.81	3.98	0.315	.382
Radar	.6433	6.3	1.80	3.40	2.012	.988
SKE	.9100	29.4	1.38	2.91	0.348	.067
INS	.9214	25.1	0.91	2.14	0.288	.129
Micro HUD (2)	.9089	32.0	1.46	3.21	0.301	.226
Integrated Communications Control	.9842	64.5	0.98	2.38	0.111	.038
Integrated Navigation Control	.8861	30.4	2.28	3.53	0.989	.126
Signal Converter	.9276	31.6	1.29	2.46	0.234	.062
Mission Computer	.9148	34.4	1.30	3.21	0.279	.149
CRT (3)	.9514	42.1	1.34	2.15	0.153	.031
Digital Scan Converter	.9806	148.3	1.62	2.88	0.089	.049

Table 20 R&M SUMMARY – AVIONICS, 2MFD

Task Oriented Manning, Training, and Tech Manuals advantages and disadvantages of each approach. CHRT does not make decisions it is simply used to quantify the impact of design and support alternatives. In doing so, it uses the best available information. The result must therefore be considered in that light.

Item	Availability	MFHBMA	R&R	FL MTTR	FL MMH/FH	Shop MMH/FH
Main Gear	.9284	29.0	0.46	2.236	0.332	0.32
Nose Gear	.9636	56.0	0.86	2.732	0.196	.009
Controls	.9857	189.0	0.96	2.738	0.396	.004
Brakes/Anti-Skid	.7451	9.0	0.60	3.078	1.710	.224
Steering System	.9668	74.0	0.96	3.342	0.136	.012
Emergency Systems	.9979	819.0	0.14	1.72	0.004	–
Wheels & Tires	.9258	22.0	1.75	1.764	0.180	.140

Table 21 R&M SUMMARY – MODIFIED LANDING GEAR

Conventional Manning, Training, and Tech Manuals

Item	Availability	MFHBMA	R&R	FL MTTR	FL MMH/FH	Shop MMH/FH
Main Gear	.9386	32.2	0.49	2.1103	0.279	.031
Nose Gear	.9688	62.2	0.94	2.6712	0.168	.008
Controls	.9870	211.2	1.06	2.7711	0.348	.004
Brakes/Anti-Skid	.7633	9.2	0.61	2.8533	1.560	.223
Steering System	.9808	74.7	0.97	3.0462	0.122	.012
Emergency Systems	.9982	863.1	0.14	1.577	0.004	–
Wheels & Tires	.9259	22.0	1.75	1.761	0.159	.141

Table 22 R&M SUMMARY – MODIFIED LANDING GEAR

Task-Oriented Manning, Training, and Tech Manuals

Maintenance manpower requirements at the squadron level were determined using the technique described in Section II. These requirements are depicted for avionics in Table 23 and for landing gear in Table 24. The equipment configuration and personnel/training/tech manual approach are noted. In Table 23, for example, a different manpower requirement is associated with each avionics configuration. A review of this data with reference to conceptual phase data (see Table 4) indicates results of similar magnitude. Both 2MFD and 3MFD avionics with the conventional option, however, now show a reduction in manpower requirements.

AFSC	Title	3MFD Conventional	2MFD Conventional	2MFD Task-Oriented	IDAMST Conventional
32850	Avionics Comm	16.1	15.3	6.7	14.8
32830		7.0	7.0	13.4	6.7
32851	Avionics Nav	14.9	13.5	7.1	12.2
32831		11.9	10.5	15.6	9.8
32854	Avionics Inertial &	2.6	6.1	2.5	1.3
32834	Radar Nav	2.4	5.3	7.6	1.4
42350	Aircraft Electrical	–	–	–	–
42330	Systems	–	–	–	–
43151	Aircraft Maintenance	16.6	17.0	15.0	14.5
43131					
53150	Machinist	0.3	0.3	0.3	–
53153	Airframe Repair	0.4	0.4	0.4	0.4
53133		0.4	0.4	0.4	0.4
32851	Integrated Avionics				1.0
32631	Components (Shop)				0.8
32852	Integrated Avionics				0.1
32631	Systems (FL)				0.7
Total		72.6	75.8	69.0	64.1

Table 23 MAINTENANCE MANPOWER REQUIREMENTS PER SQUADRON – AVIONICS

AFSC	Title	Conventional	Task-Oriented
42350	Aircraft Electrical	3.0	1.1
42330	Systems	2.1	3.5
42354	Aircraft Pneudraulics	3.8	1.5
42334		1.4	3.0
43151	Aircraft Maintenance	3.7	3.3
43131		1.5	1.4
4315W	Aircraft Maintenance	.3	.3
4313W	(Wheels)	.3	.3
4315R	Aircraft Maintenance	.9	.8
4315W	(Reclamation)	–	–
53150	Machinist	–	–
53154	Corrosion Control	.5	.5
53134			
53156	Non-Destructive	.5	.5
53136	Inspection	–	–
Total		18.0	16.2

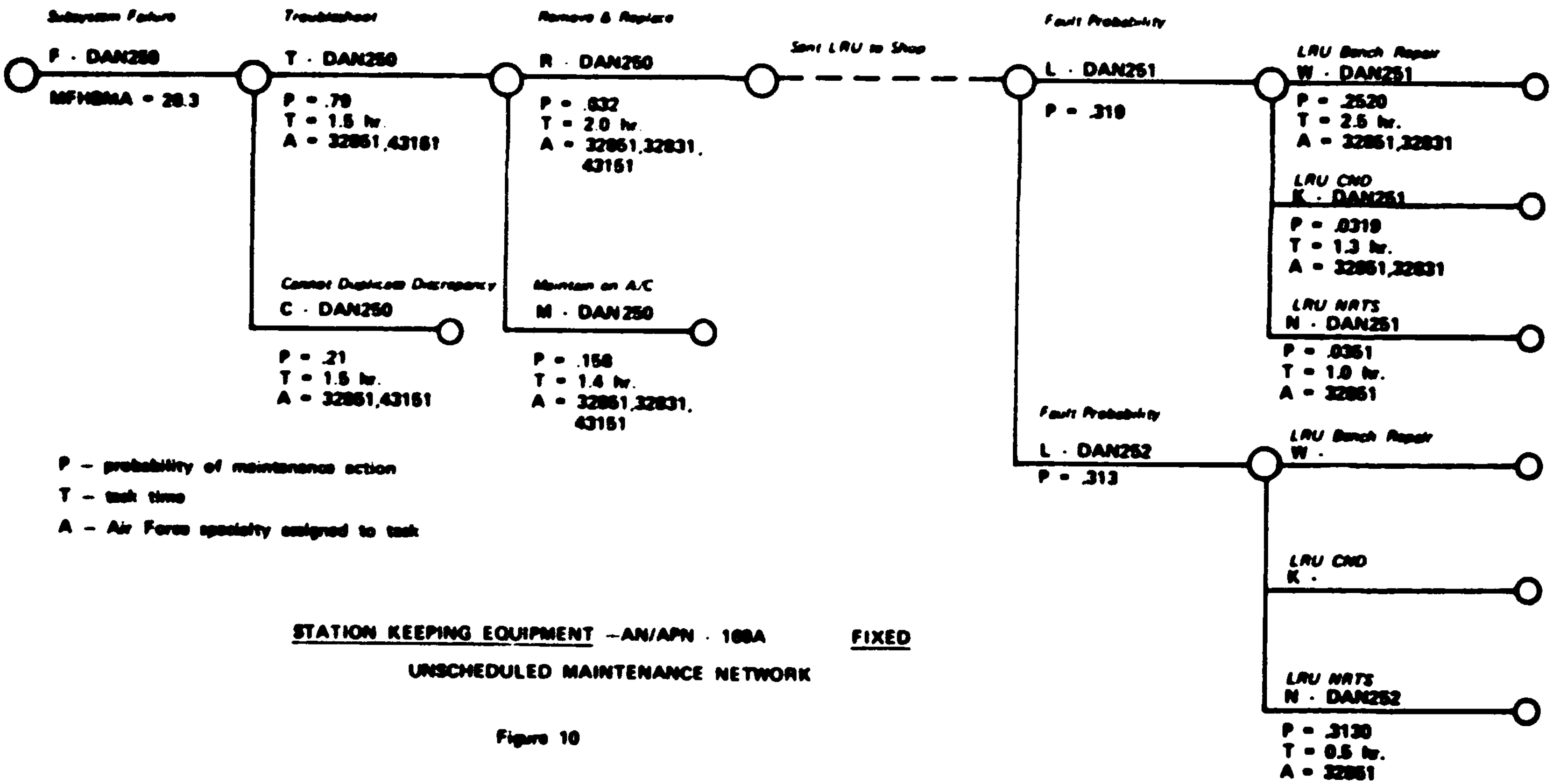
Table 24 MAINTENANCE MANPOWER REQUIREMENTS – LANDING GEAR

Additionally, the conceptual phase conclusion that the 3MFD would require more maintenance personnel than the 2MFD is no longer supported. This contradition cannot be fully explained. It may be due to the availability of more detailed and more accurate data in the validation phase, with the validation phase results being the "true" information. It may be due to random variations of data from one analysis to another, with the difference between results not significant. Furthermore, the issue is confounded when it is noted in Table 23 that use of the task-oriented approach in the validation phase reduces 2MFD personnel requirements to less than those for the 3MFD, thus reasserting the conceptual phase results that the 3MFD requires more maintenance personnel. It is obvious that research is needed to clarify this topic and to determine the validity of early predictions of manpower requirements.

The subsystem level alternative of fixed versus insertable SKE was also addressed during this phase of the demonstration. The objective here was twofold. First was the development of the technique to both isolate a single subsystem from a system maintenance network and then address this subsystem and its alternatives in terms of both scheduled and unscheduled maintenance. Second was the evaluation of the specific SKE alternative described. Both of these objectives were achieved.

The network reflecting unscheduled maintenance on the fixed SKE (Figure 10) was stripped from the 2MFD avionics and was independently assessed to quantify reliability, maintainability, and maintenance manpower requirements. This network was then modified to reflect SKE which was inserted only on flights having an SKE requirement. It was assumed that half of the flights would have an SKE requirement. The original unscheduled maintenance network was modified to reflect this 50 percent use factor by reducing the probability of subsystem failure in the original network by one half. This results in an increase in MFHBMA from 26.3 to 52.6. The modified unscheduled maintenance network is shown in Figure 11 and reflects this single change.

A scheduled maintenance network (Figure 12) was then developed to reflect the time required to insert and remove SKE on those flights for which it was required. The personnel quantity, skills, and skill levels, and times required for unscheduled removal



P – probability of maintenance action

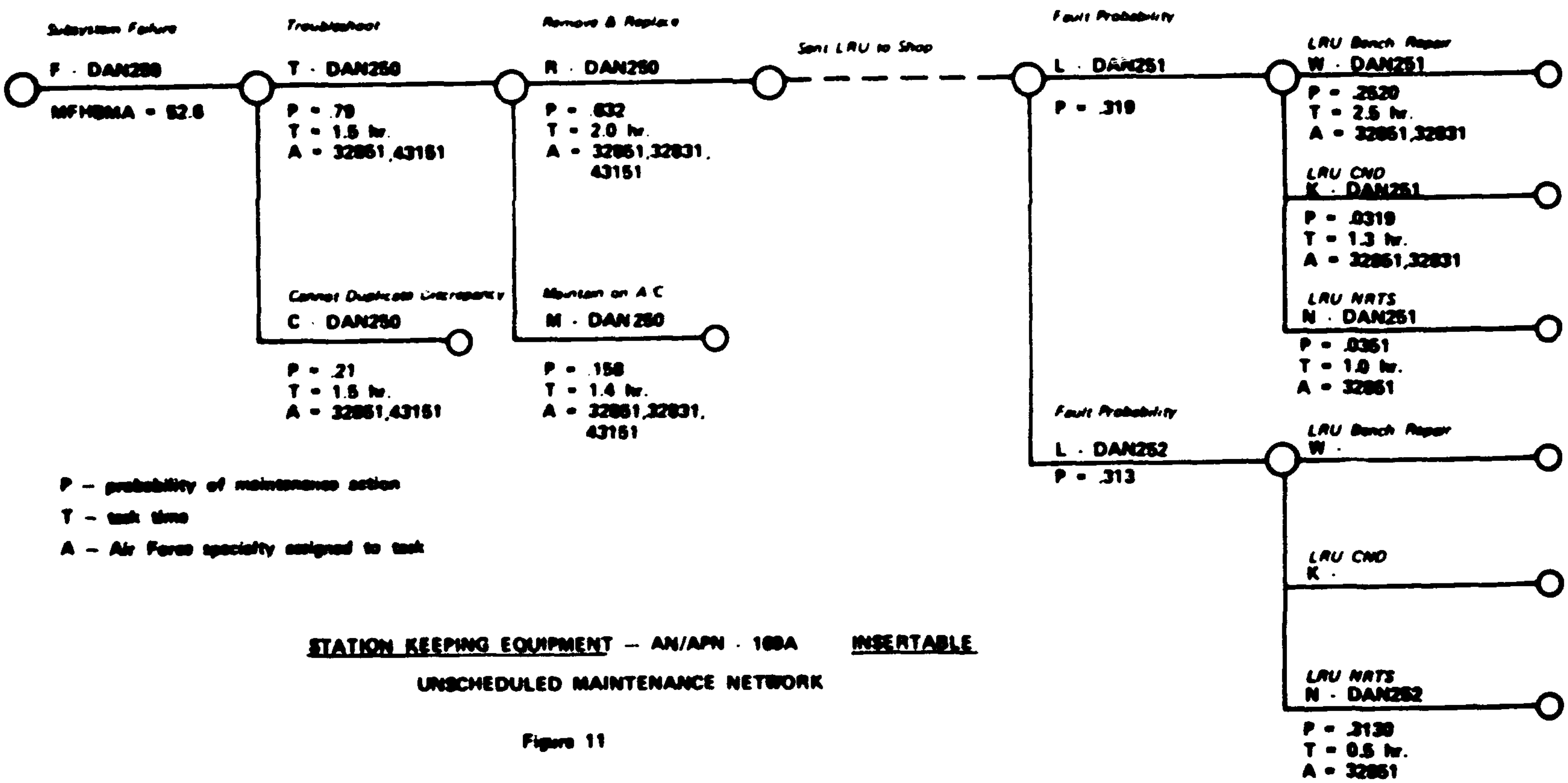
T – task time

A – Air Force specialty assigned to task

STATION KEEPING EQUIPMENT –AN/APN - 169A FIXED

UNSCHEDULED MAINTENANCE NETWORK

Figure 10



P – probability of maintenance action

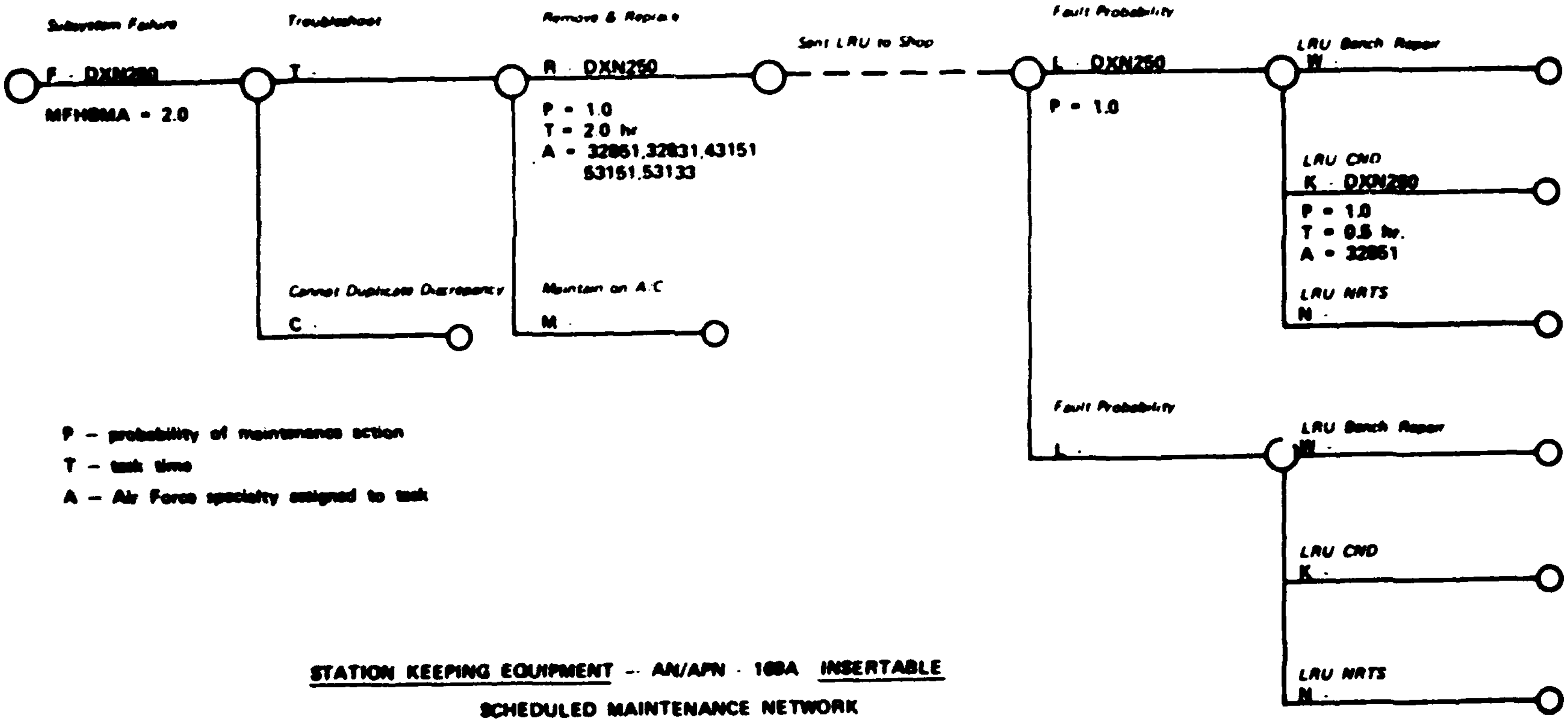
T – task time

A – Air Force specialty assigned to task

STATION KEEPING EQUIPMENT – AN/APN - 169A INSERTABLE

UNSCHEDULED MAINTENANCE NETWORK

Figure 11



P – probability of maintenance action

T – task time

A – Air Force specialty assigned to task

STATION KEEPING EQUIPMENT -- AN/APN · 169A **INSERTABLE**

SCHEDULED MAINTENANCE NETWORK

Figure 12

and replacement and shop were used for scheduled insertion and removal and shop checkout. The resulting networks were then assessed to quantify reliability, maintainability, and maintenance manpower requirements for the insertable alternative. The scheduled maintenance rate is described through the MFHBMA factor. In this case average sortie length was assumed at one hour. Since the SKE would be required on every other flight, the MFHBMA for insertion and removal is two hours.

The impact of this alternative was surprising. An insertable SKE would require a tenfold increase in SKE support personnel. Analysis of the data revealed that this manpower requirement was directly due to the time required for insertion and removal effort. This effort, as calculated, completely negated any maintenance manpower reduction due to reduced unscheduled maintenance. The next step would be to investigate and verify input data, such as insertion frequency and the insert and removal time. Is the time representative? Could the time, skills, and personnel required for insertion and removal be reduced by improved training or technical data? Is there an equipment access or location problem that could be solved by redesign or relocation? After these questions were answered, a new alternative could be described and evaluated.

In this case it was found that the scheduled maintenance rate should have been 10 hours rather than two hours. The average flight is assumed to be five hours and consists of five sorties. It is on every other flight, not sortie, that SKE is inserted. More correctly, SKE support personnel would have to double to support the insertable concept. It would be appropriate to readdress this alternative after validating the insert and removal times.

The objectives of this particular demonstration were achieved. A technique to isolate a single subsystem was developed and that subsystem and its alternative were addressed. Additionally, a technique was also developed to reflect scheduled maintenance. Finally, the results were adequate to access these two alternatives and to identify areas for continued consideration.

Operations Manpower Requirements

Operation manpower requirements were updated in this phase utilizing the prototype proposal delivery schedules. The technique used was the same as applied in the conceptual phase. Therefore no additional discussion will be provided. The data are presented in Table 25.

FISCAL YEAR														
83	84	85	86	87	88	89	90-02	03	04	05	06	07	08	09
CREWS TO BE TRAINED														
8	32	84	132	136	156	119	54	54	54	0	0	0	0	0
TOTAL OPERATIONS AND INSTRUCTOR CREWS REQUIRED														
8	40	120	240	352	472	544	544	540	506	432	312	192	72	0

CREW COMPOSITION

Pilot

Copilot

Navigator*

Loadmaster

BASIC REQUIREMENT	TRAINING REQUIREMENT DERIVATION
2-Crews/Aircraft	FY83-89 New Crew Requirement + 10% Turnover
256–Unit Equipped Aircraft Peak	FY90-04 10% Turnover
16–Training Aircraft Peak	FY05-09 10% Turnover Satisfied by Reassignment

*Four-man flight crew only

Table 25 OPERATIONS MANPOWER REQUIREMENTS LIST PER FY

Scope and Magnitude of Training and Technical Manuals for Maintenance Personnel

Specialty training course estimates remain the same as developed for the conceptual phase. The technique described in Section II was used. Technical training data were not addressed due to delays in obtaining comparability data from the C-141 technical training course. Information is available now, however, and technical training will be addressed in the full-scale development phase of this demonstration.

Extensive work was done during the validation phase demonstration to refine the job guide content and cost algorithms. A significant portion of this work was accomplished as a special study in support of the F-16 SPO technical documentation negotiations. This newly acquired information has been employed during this phase with the following results.

Page types were defined in the conceptual phase as narrative, schematic, and pictorial. Table 26, a new development, now identifies a more extensive list of page types and indicates the type manual in which they would be used by a C (conventional) or T (task oriented). Task-oriented manuals are not covered for shop activities since they are not presently used in that area.

Page Type	TS		NTS	
	F/L	Shop	F/L	Shop
Narrative	C/T	C	C	C
Half Tone Art	C	C	C	C
Half Tone Explosion		C		C
Electronic Line Art	C	C		C
Exploded Line Art		C		
Fault Isolation Chart	T			
Fault Isolation Schematic Block	T	C		
Access Line Art	T			
Fault Isolation Schematic Flow	T	C		
Fault Isolation Schematic Mech/Hyd	T	C		
Job Guide Narrative			T	
Job Guide Illustrations			T	

Table 26 PAGE TYPES FOR CONVENTIONAL (C) AND TASK-ORIENTED (T) MANUALS

The determination of the number and type pages required for each type manual is accomplished by algorithm. The input data required are the quantity of subsystems, LRUs, and SRUs within a system, and the quantity of actions performed at the subsystem, LRU, and SRU level. The algorithms were developed after an extensive review of current technical data manuals and were derived through regression analysis using current F-16 technical manuals as the estimating baseline. The complete set of algorithms is given in Volume II along with the technical manual content estimate for each equipment configuration addressed in this phase.

The algorithm developed to predict the content of a fault isolation manual to support the task-oriented approach to flight line troubeshooting is provided here as an example. The algorithm determines the number of maintenance actions, pictorials, and schematics as a function of the number of subsystems and LRUs. In this case:

Number of actions = 2 actions/subsystems + 2 actions/LRU
Number of pictorials = 2 pictorials/LRU
Number of schematics = 1 schematic/subsystem + 1 schematic/LRU

The total pages are then calculated as follows:

Number of pages = 1 action page/action + 1/2 narrative page/LRU
+ 1 pictorial page/pictorial
+ 2 schematic pages/subsystem
+ 1 schematic page/LRU

In this type manual the following page type relationships are applicable:

action page = fault isolation chart
narrative page = narrative
pictorial page = access line art
subsystem schematic page = fault isolation schematic block
LRU schematic page = fault isolation schematic flow

Additional details regarding page types are provided in Reference 11.

All algorithms were applied during this phase of the demonstration. The results for the 2MFD conventional and task-oriented manuals are presented in Tables 27 and 28, respectively. The difference in content between the two general types is found in the flight line manuals.

Cost estimates for these manuals were obtained and are shown under SOC data. Estimates are based on individual page costs developed from a detailed analysis of each page type considered. Page costs include page preparation, verification and validation, and contract loading. This cost information is also included in Volume II.

Page Type	TS (pages)		NTS (pages)	
	F/L	Shop	F/L	Shop
Narrative	107	267	162	928
Half Tone Art	54	298	27	267
Half Tone Explosion		267		27
Electronic Line Art	54	1012		533
Exploded Line Art		108		
Fault Isolation Chart				
Fault Isolation Schematic Block				
Access Line Art				
Fault Isolation Schematic Flow				
Fault Isolation Schematic Mech/Hyd				
Job Guide Narrative				
Job Guide Illustrations				
Total Pages	215	1947	189	1738

Table 27 2MFD AVIONICS CONVENTIONAL MANUALS

Page Type	TS (pages)		NTS (pages)	
	F/L	Shop	F/L	Shop
Narrative	27	267		928
Half Tone Art		298		267
Half Tone Explosion		267		27
Electronic Line Art		1012		533
Exploded Line Art		108		
Fault Isolation Chart	180			
Fault Isolation Schematic Block	52			
Access Line Art	108			
Fault Isolation Schematic Flow	54			
Fault Isolation Schematic Mech/Hyd				
*Job Guide Narrative			540	
*Job Guide Illustrations			540	
Total Pages	401	1952	1080	1736

*5x8

Table 28 2MFD AVIONICS TASK-ORIENTED MANUALS

Training for Operations Personnel

In the validation phase, the preliminary operator task list prepared in the conceptual phase is expanded in detail. For demonstration purposes, an expanded task list compatible with 2MFD avionics was prepared for pilot and copilot duties. This expanded task list which is enclosed in Volume II as part of the "Personnel, Training, and Job Guide Section of the AMST Integrated Logistics Support Plan." It was developed from validation phase data. Specifically, AFFDL-TM-76-45-FGR, Advanced Medium STOL Transport Crew Systems Technology Program, Austere Cockpit Design, Mission Scenario was used. Although the TM was prepared for the 3MFD avionics configuration, the results were adapted to a 2MFD avionics configuration by dropping those tasks which were eliminated by integrated controls and by redistributing the remainder between the pilot and copilot.

The expanded task list was reviewed against the conceptual phase estimate of operator course length, Table 9, and the previous results were supported. The validation phase estimate of operator course length, however, is more detailed and is shown in Table 29.

PHASE	SEGMENT	DURATION*
Initial	Classroom	14
	Simulator	16
	Flying	15
	Written	1
	Travel	3
		49 days
Mission	Classroom	14
	Flying	28
	Written	1
		43 days

*Assumes 5-day week schedule and includes weekends.

Table 29 OPERATOR COURSE LENGTH

SOC

System ownership costs were derived in the validation phase by selective application of the DAIS LCC model. This model was being developed under a separate effort is now automated and driven directly by the R&M model. Reference material is identified in the Bibliography (reference 5). The output of the R&M model, as run for each AMST avionics and landing gear option, was combined with a unique AMST SOC data base which is also provided in Volume II. The output was then processed through the system ownership cost modules of the LCC model.

With this improved cost model, the costs could now be subdivided into support investment (non-recurring costs) and operating and support (recurring costs). SOC was obtained for all desired cost factors except costs of the initial maintenance training course, support equipment, and support equipment maintenance. The cost data are presented in 1976 dollars and are shown in Table 30. The areas not covered will be thoroughly investigated during the full-scale development phase demonstration. Disposal costs were not addressed since only two individual systems of the AMST, avionics and landing gear, were under consideration.

Cost Area	Avionics 2MFD Conventional	Avionics 2MFD Task Oriented	Avionics 3MFD Conventional	Avionics IDAMST Conventional	Landing Gear Conventional	Landing Gear Task Oriented
SUPPORT INVESTMENT						
Spares	52,146,923	51,797,001	51,900,971	63,317,288	4,918,213	4,898,116
Maintenance Manuals Shop	1,079,845	1,079,645	1,020,828	1,204,846	106,718	106,718
Maintenance Manuals Flight Line	109,483	286,637	102,262	115,201	189,820	886,448
Inventory Management	3,499	3,499	2,637	12,880	8,722	8,722
TOTAL	53,339,550	53,166,782	53,026,686	66,650,195	5,202,273	5,[illegible],004
OPERATING AND SUPPORT/YR						
On Equipment Maintenance	22,294,936	20,811,516	21,819,208	18,388,080	6,151,715	5,888,721
Off Equipment Maintenance	8,281,830	8,031,506	7,764,386	7,399,768	982,402	879,883
Maintenance Training	989,062	431,383	580,040	886,087	643,974	478,851
Aircrew	31,961,888	31,961,888	42,811,128	31,961,888	–	–
Aircrew Training	8,490,000	8,490,000	11,307,000	8,480,000	–	–
Spares	2,291,388	2,276,323	2,206,843	2,796,777	219,838	218,822
Depot Repair	11,293,380	11,237,947	10,716,816	9,298,223	2,238,280	2,228,337
Maintenance Manual Maintenance	88,1841	123,988	84,230	98,003	20,880	91,388
Software Support	33,086	33,086	–	438,916	–	–
Inventory Management	72,313	72,313	60,963	106,823	48,067	48,067
TOTAL/YR	86,388,886	83,166,920	97,168,383	79,782,234	10,202,888	9,723,783

Table 30 AMST SYSTEM OWNERSHIP COST DATA

HR and SOC Impact and High Drivers

The HR and SOC impact was described in Section II as the summarization and presentation of HR and SOC data for baselines or alternatives and the analysis of those data to determine feasibility, acceptability, or need for further reiteration, or consideration. Just as more accurate and efficient methods were devised to develop the HR and SOC data, a better method to summarize, present, and analyze the data was also sought. Two formats were devised, an abbreviated impact analysis and a detailed impact analysis. Samples of each format were developed for the 2MFD vs 3MFD avionics option with conventional ISD/JGD and the conventional versus task-oriented ISD/JGD option for 2MFD avionics.

The abbreviated format addresses all HR considerations and SOC (Tables 31 and 32). It quantifies availability (a function of reliability and maintainability), maintenance manpower, training costs per year, job guide documentation investment cost, and job guide documentation maintenance costs per year. The abbreviated format also presents SOC in terms of support investment cost and operating and support costs per year. Risk areas, problems, and recommendations are also addressed. Risk areas and problems may be determined from a review of the HR and SOC data for "high drivers" within the alternatives. The method of identifying "high drivers" and sample data were presented in Section II. The method remains the same. Risk areas associated with human resources may also be identified by judgment. This was the case with the low operational risk identified. This risk area specifically refers to the capability of a pilot and a copilot to perform the more intense and complex tactical missions with the austere avionics suite envisioned. The recommendations again are developed from the human resource and system ownership cost viewpoints and may be either negated or supported by operations, design, and acquisition considerations.

The detailed impact analysis format (Tables 33 and 34) expands on the system ownership cost, manpower, and technical areas. It also adds acquisition cost (system investment), operations, and schedule data. This format appears to be the most desirable and with the addition of problems and recommendations should provide a complete yet rather simplified display.

Factor	2MFD	3MFD	Δ
Availability	.0840	.0981	+.0141
Maintenance Manpower	1213	1163	− 50
5 Level	842	815	− 27
3 Level	371	348	− 23
Operations Manpower	1632	2176	+544
ISD $/Year	9,089,092/yr	11,906,040/yr	+2,816,948/yr
JGD $	1,189,128	1,123,077	− 66,051
JGD $/Year	89,184/yr	84,230/yr	− 4,954/yr
Support Investment $	53,339,560	53,026,695	− 312,865
Operating and Support (annual) $/Year	85,386,866/yr	97,168,393/yr	+11,781,527/yr
Risk Area	Operational—low		

PROBLEMS: HF RADIO AND RADAR—LOW AVAILABILITY, EXCESSIVE R&R AND FL MMH/FH
INTEGRATED NAVIGATION CONTROL—EXCESSIVE R&R TIME

RECOMMENDATIONS: ACCEPT 2MFD APPROACH. VALIDATE COMPARABILITY DATA.
CONSIDER REDESIGN OR ALTERNATIVES FOR HF RADIO AND RADAR.
TIGHTEN SPECIFICATION ON INTEGRATED NAVIGATION CONTROL.

Table 31 ABBREVIATED IMPACT ANALYSIS — AVIONICS
2MFD vs 3MFD
CONVENTIONAL ISD/JGE

Factor	Conventional ISD/JGD	Task-Oriented ISD/JGD	Δ
Availability	.0840	.1105	+.0265
Maintenance Manpower	1213	1104	−109
5 Level	842	512	−330
3 Level	371	592	+221
Operations Manpower	—	—	
ISD $/Year	9,089,092/yr	8,921,383/yr	−167,709/yr
JGD $	1,189,128	1,366,282	+177,154
JGD $/Year	89,184/yr	123,969/yr	+ 34,785/yr
Support Investment $	53,399,560	53,166,782	−232,786
Operating and Support (annual) $/Year	85,386,866/yr	83,168,920/yr	−2,217,946/yr
Risk Area	Operational—low	Operational—low	

PROBLEMS: HF RADIO AND RADAR—LOW AVAILABILITY, EXCESSIVE R&R AND FL MMH/FH
INTEGRATED NAVIGATION CONTROL—EXCESSIVE R&R TIME

RECOMMENDATIONS: ACCEPT TASK-ORIENTED ISD/JGD APPROACH. VALIDATE COMPARABILITY DATA. TIGHTEN SPECIFICATION ON INTEGRATED NAVIGATION CONTROL.

Table 32 ABBREVIATED IMPACT ANALYSIS — 2MFD AVIONICS

	Avionics 2MFD Conv	Avionics 3MFD Conv
SYSTEM INVESTMENT (millions $)		
Hardware	243.190	162.720
Software	200	000
TOTAL	243.390	162.720
SUPPORT INVESTMENT (millions $)		
Support Equipment	----	----
Spares	52.150	51.900
Maintenance Manuals Shop	1.080	1.080
Maintenance Manuals Flightline	110	.102
Inventory Management	003	003
TOTAL	53.343	53.086
MANPOWER FACTORS		
Maintenance Personnel Total	1213	1163
5 Level	842	815
3 Level	371	348
Maintenance Skills	7	7
Air Crew Total	1789	2386
Officer	1182	1788
Enlisted	607	607
OPERATIONS RISK	MOD	LOW
SCHEDULE RISK	LOW	LOW

	Avionics 2MFD Conv.	Avionics 3MFD Conv.
OPERATING AND SUPPORT/YR (millions $/yr)		
On Equipment Maintenance	22.296	21.820
Off Equipment Maintenance	8.261	7.764
Maintenance Training	.600	.800
Aircrew	31.982	42.811
Aircrew Training	8.480	11.300
Spares	2.291	2.206
Depot Repair	10.293	10.716
Support Equipment Maintenance	----	----
Maintenance Manual Maintenance	.080	.084
Software Support	.033	.000
Inventory Management	.072	.060
Disposal	----	----
TOTAL/YR	85.387	97.169
TECHNICAL CONSIDERATIONS		
Confidence	HI	HI
Complexity	MOD	LOW
Risk	MOD	LOW
MMH/HF (S)	3.3	3.2
MMH/FH (F/L)	8.2	8.9
MFHBMA	1.13	1.33

DETAILED IMPACT ANALYSIS – AVIONICS

2MFD VS 3MFD

CONVENTIONAL ISD/JGD

Table 33

	Avionics 2MFD Conv.	Avionics 2MFD T/O
SYSTEM INVESTMENT (millions $)		
Hardware		
Software		
TOTAL		
SUPPORT INVESTMENT (millions $)		
Support Equipment	----	----
Spares	$2.190	$1.797
Maintenance Manuals Shop	1.080	1.080
Maintenance Manuals Flightline	.110	.287
Inventory Management	.003	.003
TOTAL	$3.383	$3.167
MANPOWER FACTORS		
Maintenance Personnel Total	1213	1104
5 Level	842	512
3 Level	371	592
Maintenance Shifts	7	7
Air Crew Total	1789	1789
Officer	1192	1192
Enlisted	597	597
OPERATIONS RISK	MOD	MOD
SCHEDULE RISK	LOW	LOW

	Avionics 2MFD Conv.	Avionics 2MFD T/O
OPERATING AND SUPPORT/YR (millions $/yr)		
On Equipment Maintenance	22.295	20.512
Off Equipment Maintenance	8.291	8.032
Maintenance Training	.800	.431
Aircrew	31.962	31.962
Aircrew Training	8.480	8.480
Spares	2.291	2.275
Depot Repair	11.283	11.237
Support Equipment Maintenance	----	----
Maintenance Manual Maintenance	.089	.124
Software Support	.022	.033
Inventory Management	.072	.072
Disposal	----	----
TOTAL/YR	85.387	83.166
TECHNICAL CONSIDERATIONS		
Confidence	HI	HI
Complexity	MOD	MOD
Risk	MOD	MOD
MMH/FH (S)	3.44	3.33
MMH/FH (F/L)	8.21	8.17
MFHBMA	1.11	1.20

DETAILED IMPACT ANALYSIS – 2MFD AVIONICS

CONVENTIONAL VS TASK ORIENTED – ISD/JGD

Table 34

Training and Job Guide Documentation Products

The planned product for the validation phase was a personnel/training/job guide plan. The goal was to provide an input to a validation phase integrated logistics support plan (ILSP) to a level of detail beyond that normally expected in this phase. The product, "The Personnel, Training and Job Guide Section of the Integrated Logistic Support Plan for the Advanced Medium STOL Transport" is presented in Volume II. The scope and detail of this coordinated section was compared with similar sections of the F-16 full-scale development ILSP. The AMST product, based on prototype phase personnel, training, and technical manual data derived through the CHRT process, contained more useful and detailed data.

The feasibility of determining from validation phase data the emphasis to be given a task in training and/or the technical manual was also explored with positive results. This early determination is necessary so that training and technical manual developers may better describe, plan, and prioritize the full-scale development training and technical manual efforts. The determination has been automated with a prototype task intensity matrix program. The determination is based on task data drawn from the R&M output as interpreted by the task intensity program. The complete interpretation technique will be described in a subsequent technical report.

The task intensity program identifies a requirement for training and/or technical manual coverage and quantifies the requirement as low (1), medium (2), or high (3). Tasks are simply categorized as flight line non-troubleshoot, flight line troubleshoot, and shop repair. The flight line tasks are addressed at the subsystem level, while shop repair is addressed at the LRU level. The determination has been performed for the 2MFD avionics and landing gear and is included in "The Personnel, Training, and Technical Manual Section of the Integrated Logistic Support Plan for the Advanced Medium STOL Transport."

The presentation format is called a task intensity matrix. A portion of the Task Intensity Matrix for the 2MFD avionics with the task-oriented option is shown in Table 35. The sample shown is for FAC110 (HF Radio-AN/ARC-123) and DAC210 (VHF/FM Radio-FM-622A). The indentured codes FAC111-FAC112 and DAC213, represent LRUs which are repaired in the shop. Estimates of the training/tech manual coverage required is presented as a fraction. For example, the 1/3 in the flight line troubleshoot column opposite DAC210 represents a low requirement for training coverage over a high requirement for tech manual coverage.

CHRT DEMO - AMST AVIONICS 2-MAN CREW - PROTOTYPE PHASE, TASK ORIENTED

TASK INTENSITY MATRIX

EQUIPMENT	FLIGHTLINE NONTROUBLESHOOT	FLIGHTLINE TROUBLESHOOT	SHOP REPAIR
FAC110	2/2	3/3	
FAC111			2/2
FAC112			2/2
FAC113			1/3
FAC114			2/2
FAC115			2/2
FAC118			1/3
DAC210	2/2	1/3	
DAC213			2/2

Table 35 TASK INTENSITY MATRIX

3.4 CONCLUSIONS - VALIDATION (PROTOTYPE) PHASE

The results of the validation (prototype) phase demonstration support the conceptual phase conclusion that HR and SOC data can be developed for a system through a logical, rational, and repeatable process. The specific conclusions follow.

A. Application of the CHRT process and CDB is feasible in the validation phase.

1. The more detailed data required for the continued CDB evolution required to support a more detailed design can be obtained in the validation phase.
2. The CHRT process is sensitive at the subsystem level and can be used to address components of the subsystem.
3. The personnel/training/technical manual concept, whether conventional, task-oriented, or a mix, can be reflected in the maintenance action networks and its influence can be directly reflected in the HR and SOC estimates.

B. The validation phase products have been identified and representative samples have been provided and evaluated for utility.

1. The HR and SOC derived through the CHRT process during the validation phase were the same categories as conceptual phase estimates but reflect more accurate and detailed input data. These estimates allow the system manager to influence the selection of the full-scale development baseline, to quantify risk/payoff areas, and to identify viable alternatives for continued consideration during full scale development.
2. The estimates derived allow the early development of a detailed personnel/training/job guide plan.
3. A newly developed validation phase product, the task intensity matrix, can provide an early indication of unusual requirements in training and job guide documentation.

C. The CDB, as modified, supports the CHRT process.

1. An updated and expanded SOC model has been added.
2. The task intensity matrix tool has been added.

D. Inadequacies and/or inconsistencies in the CHRT process and the CDB have been identified. All have been either corrected or earmarked for future consideration.

1. The R&M model must be improved to effectively quantify support equipment needs as well as manpower. This must be done to quantify support equipment costs and to provide complete R&M and LCOM compatibility.
2. Technical training must be addressed to totally represent training costs per year.
3. A technique to determine the costs to establish a training course should be considered.
4. A technique should be developed to address the phase in and phase out of a system. Data presently reflect a fully phased-in system.
5. Activity was not initiated on LCOM during this phase, although LCOM should be run during validation on alternatives of specific interest. LCOM runs will be made during the full development phase demonstration. Additionally, R&M and LCOM results will be compared for compatibility.

The conclusions made during this second part of the CHRT demonstration will be reconsidered in the third and final part of the demonstration. Final conclusions will then be addressed in a subsequent technical report.

3.5 VALIDITY OF THE PREDICTED DATA

A central issue is the validity of the conceptual phase requirements and the validation phase requirements which were predicted by the CHRT technique. Indeed, this is a central issue to all predictive methodologies used throughout system acquisition studies. In this demonstration of CHRT, there is no external evidence regarding the validity of the predicted requirements. Confidence in the predicted manpower, reliability, maintainability, technical data, training, and cost requirements is dependent upon confidence in the logic of the procedure, the reasonableness of the assumptions, and the relevance of the input data.

Clearly, caution must be used in applying the results of CHRT analyses to engineering and management decision-making during system acquisition. Clearly, new investigations are needed to address this central issue of the validity of predicted requirements. However, CHRT, even in its present form, is a valuable tool for the weapon system engineer and the weapon system manager. CHRT provides a systematic, quantitative, and trackable procedure for addressing the human resource, logistic, and ownership cost issues involved in a system acquisition program. CHRT, therefore, represents a significant advance over current practices.

IV. FULL SCALE DEVELOPMENT DEMONSTRATION PLANS

The demonstration of CHRT as applied in a full-scale development phase will be conducted between 16 August 1978 and 15 May 1979. The AMST minimum engineering development (MED) phase was expected to be the demonstration vehicle and provide both a real time source of data and an opportunity for a practical application of CHRT. The AMST program, however, is delayed, and all data are secured as source selection sensitive. AMST MED phase data, therefore, will be simulated with projected data based on actual hardware from the C-141 landing gear and existing avionics. HR and SOC data will be developed for the 2MFD avionics and C-141 landing gear. Alternatives will address different personnel, training, and job guide documentation approaches; and different detailed designs within the avionics and landing gear systems.

Significant effort will also be expended in the development of support equipment maintenance action networks for the landing gear. These support equipment networks will be integrated with the landing gear maintenance action networks and run on LCOM to quantify requirements as a function of both demand on support equipment and availability of support equipment.

Heavy emphasis will also be placed on the development of the training and technical manual products described in AFHRL-TR-73-43 and as perceived by the CHRT process. Intermediate products will include an annotated task identification matrix (ATIM), ISD/JGD decision ground rules, a level-of-detail guide, and the test equipment and tool use form. The final products will be a full range of training plans and job guide documentation samples supporting both the conventional and task-oriented approach. These products will all be included in the implementing documentation for the CHRT process.

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